IMPLEMENTATION OF BUILDING INFORMATION MODELLING IN THE DOMINICAN REPUBLIC CONSTRUCTION INDUSTRY

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This work or any part thereof has not previously been presented in any form to the University or to any other body whether for the purposes of assessment, publication or for any other purpose (unless otherwise indicated). Save for any express acknowledgements, references and/or bibliographies cited in the work, I can confirm that the intellectual content of the work is the result of my own efforts and of no other person.

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Date 12-05-2020..

ABSTRACT

The Dominican Republic (D.R.) is a Caribbean nation whose construction industry is key in the economic growth and development of the country; however, the productivity of the sector is being affected by inefficient traditional practices. The increased use and proven benefits of Building Information Modelling worldwide suggest that its implementation could be of great help in decreasing current issues in the Dominican construction industry. Nonetheless, there is no empirical work that sets the scene of the implementation of BIM in the country to make suggestions for its implementation. Therefore, this research aimed to bridge this gap by investigating the status of BIM in the D.R. and developing a framework to facilitate its implementation. For this purpose, a review of literature on BIM and emerging concepts, processes and technologies was undertaken. Furthermore, the initiatives and key players of BIM implementation worldwide were studied, which allowed the identification of the critical enabling factors for country-wide BIM implementation. A qualitative approach was adopted to carry out this research. The qualitative inquiry involved semi-structured interviews and was divided into two phases: the preliminary and the main study. In the preliminary study, eleven interviews were conducted with construction organisations to appraise and document BIM awareness and BIM implementation in the Dominican construction industry. In the main study, twenty-eight interviews directed to construction organisations were conducted to attain the same objective. This phase of the study also included interviews directed to professionals involved with the diffusion of BIM knowledge to explore and document the presence of BIM Education in the country, from which eight interviews were carried out. The data was analysed with the method of content analysis.

The research concluded that the Dominican Republic is a BIM infant country. Most organisations are not implementing BIM, and current BIM approaches are mainly single-disciplinary, principally in Architecture. Implementation strategies are incomplete, primarily focusing on the provision of training to selected staff. Drivers to implement BIM in the country include BIM benefits, competitive advantage and pressure from external partners. Hitherto, there is only BIM training and different modes of dissemination of BIM knowledge in the country. Nonetheless, efforts to integrate BIM into university curricula were identified. Challenges hindering the implementation of BIM in the country were explored, and initiatives to propel the implementation were proposed. A framework for implementing BIM in the Dominican construction industry was developed and validated to confirm its suitability for the Dominican construction industry. Recommendations for industry practitioners, government, and academics have been put forward. This research contributes to the body of knowledge in the area of country-wide BIM implementation, BIM education, and the implementation of BIM at an organisational level.

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ABBREVIATIONS

AEC	Architecture, Engineering and Construction
AGC	Association of General Contractors
AI	Artificial Intelligence
AIA	American Institute of Architects
Agesc	Association of Design Managers and Coordinators
API	Application programming interface
AR	Augmented Reality
AsBEA	Brazilian Architectural Firms Association (Translated from Portuguese)
BAF	BIM Academic Forum
BCA	Building and Construction Authority
BIM	Building Information Modelling
BRE	Building Research Establishment
BSI	British Standards Institution
CABR	China Academy of Building Research
CAD	Computer-aided design
CCS	Cuneco Classification System
CDE	Common Data Environment
CE-BIM	Strategic Committee of BIM Implementation (Translated from Portuguese)
CIBSE	Chartered Institution of Building Services Engineers
CIC	Construction Industry Council
CIOB	Chartered Institute of Building
CIRIA	Construction Industry Research and Information Association
CLVC	Centre for Lean and Virtual Construction
COBie	Construction Operations Building Information Exchange
CORENET	Construction Real Estate NETwork
CORFO	Corporation of Production Development (Translated from Spanish)
CPIC	Construction Project Information Committee
DevB	The Works Branch of the Development Bureau
DLT	Distributed Ledger Technology
DOM	Directorate of Military Projects
D.R.	Dominican Republic
EWG	Education Working Group
FIIC	Inter-American Federation of the Construction Industry
FinTech	Financial Technology
GSA	General Services Administration
HA	Housing Authority

HKIBIM	Hong Kong Institute of Building Information Modelling
I.Struct.E	Institute of Structural Engineers
ICE	Institution of Civil Engineers
ICT	Information and Communications Technology
IFC	Industry Foundation Classes
INCONET	Inter-American Red of Innovation in Construction
IT	Information Technology
IoS	Internet of Services
IoT	Internet of Things
IPD	Integrated Project Delivery
KPI	Key Performance Indicators
LOD	Levels of Development
LOF	Learning Outcomes Framework
MDIC	Ministry of Industry, Exterior Trades and Services
MOHURD	Ministry of Housing and Urban-Rural Development
MOPC	Ministry of Public Works and Communications
NBIMS	National BIM Standard
NBS	National Building Specification
NDT	National Digital Twin
NIBS	National Institute of Building Sciences
NIST	National Institute of Standards and Technology
OCA	Office of the Chief Architect
ONE	National Office of Statistics (Translated from Spanish: Oficina Nacional de Estadistica)
ONNCCE	National Organisation for Standardisation and Certification of Construction and Building (Translated from Spanish: Organismo Nacional de Normalizacion y Certificacion de la Construcción y Edificacion)
OPUS	Unified system of the construction process
PBS	Public Building Services
R&D	Research and Development
RFID	Radio-Frequency Identification
RIBA	Royal Institute of British Architects
RICS	Royal Institution of Chartered Surveyors
ROI	Return of Investment
SEIL	Secretariat of Infrastructure and Logistics
SMEs	Small and Medium Enterprises
SIM	Singapore Institute of Management
SindusCon	Construction Union
USACE	U.S. Army Corps of Engineers

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I would like to thank my family and loved ones for supporting and encouraging in all this research journey. They know more than anyone all the sacrifices I have made to get to this point.

DEDICATION

This Thesis is dedicated to:

My family

RESEARCH OUTPUT

Conference papers:

- Silverio, A.K., Suresh, S., Renukappa S. and Heesom, D. (2017b) Building Information Management (BIM) education in the Dominican Republic: An empirical study *International Conference on Sustainable Futures.,* 26-27 of Nov. 2017. Applied Science University, Bahrain.

Journal article:

- Silverio, A.K., Suresh, S., Heesom, D. and Renukappa, S. (2017a) BIM Education Framework for Clients and Professionals of the Construction industry. *International Journal of 3-D Information Modeling (IJ3DIM)* [online]**, 6**(2), pp. 57-79.

CHAPTER 1: INTRODUCTION

This introductory chapter presents a statement of the research problem and discusses the research questions, research aim and objectives, research methodology and the scope and limitations of the research. The structure of the thesis is also illustrated, summarising the content of each chapter.

1.1 Statement of the research problem

Construction is an important industry worldwide and is one of the largest sectors in the world economy, with approximately $10 trillion spent yearly on construction-related goods and services. Nonetheless, in comparison with other industries, the construction industry has experienced problems to evolve its methods, and its productivity has been affected accordingly (Mckinsey Global Institute, 2017). Many construction projects have suffered from issues such as poor quality, time delays and cost overrun. The most common reasons as to this productivity decrease can be attributed to lack of communication, insufficient exchange of project information, low productivity percentages, high rates of rework and inefficiency, adversarial relationships between partners, constant disagreements, and lack of innovation (Ahuja, Sawhney and Arif, 2017). The industry requires a more productive approach, which can be achieved through the implementation of digital technologies (Mckinsey Global Institute, 2017). Currently, there is some indication of digital transformation within the construction industry with the emergence of Building Information Modelling (BIM) (Li, Greenwood and Kassem, 2019).

BIM is a revolutionary method that has quickly reformed the way buildings are conceived, designed, built and operated (Hardin and McCool, 2015). BIM can be defined *as "a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building life cycle"* (Succar, 2009). BIM enables a more integrated design and construction process and provides significant benefits, which include and are not limited to: early collaborative decision making, early building information capture, virtual mock-ups and models, clash detection, integrated procurement, interoperability capabilities, more energy-efficient solutions, less design coordination mistakes, fewer documents errors, more accurate cost estimations, improved construction results, lower construction costs, decreased production cycle times, optimal asset performance, use throughout the building life cycle, improved data sharing between disciplines, and project team benefits (Azhar, 2011; Barlish and Sullivan, 2012; Bryde, Broquetas and Volm, 2013; Cao *et al.*, 2015; Ghaffarianhoseini *et al.*, 2017; Mahamadu *et al.*, 2017; Sacks *et al.*, 2018).

BIM implementation is rapidly increasing around the world. As per the market research report "Building Information Modelling Market - Global Industry Analysis, Size, Share, Growth, Trends, and Forecast 2015 – 2022", the global BIM market was valued at US$2.76 bn in 2014 and is predicted to be at US$11.54 bn by 2022. The growth of the

BIM market has been mainly driven by the need for more efficiency, better understanding of the whole project lifecycle and the enhancement of workflows (BIM Wiki, 2018b). Government entities engaged with construction activities as well as major private owners have introduced initiatives to propel and mandate the use of BIM on their projects (McGraw-Hill Construction, 2014a; Ghaffarianhoseini *et al.*, 2017; BIM Wiki, 2018b).

Despite its great potential and evolution over the years, the implementation of BIM has been lower than expected (Cao *et al.*, 2015; Rahim and Zakaria, 2017), limited to the technical level (Hua, 2014) and has not been fully achieved even in leading markets (Ghaffarianhoseini *et al.*, 2017). Global adoption of BIM has been slow because of the apparent challenges and risks at this phase of the technology's development and its supporting methods and standards (Li *et al.*, 2019). BIM adoption also varies significantly by country and level of economic development (World Economic Forum, 2018). Mehran (2016) noted that the adoption of BIM has been slow, particularly in late adopter countries. Bui, Merschbrock and Munkvold (2016); Jayasena and Weddikkara (2013); and Ismail, Chiozzi and Drogemuller (2017) further stated that BIM is being adopted progressively in developed countries, but the adoption levels in emerging or developing countries are low.

Moreover, there is a paucity of BIM research in these countries before 2013. Ahuja *et al.* (2018) discussed that there is not enough information available about BIM adoption patterns in emerging markets. Moreover, they pointed out that contrary to developed countries, developing countries do not have a proper industry-wide direction to assist the BIM adoption journey.

1.1.1 The construction sector in the Dominican Republic

The Dominican Republic (D.R.) is a Caribbean country that occupies two-thirds of the island of Hispaniola. It is surrounded by the Caribbean Sea, the North of the Atlantic Ocean and the east of Haiti. This country has been generally known for being an exporter of coffee, sugar and tobacco. However, agriculture has been surpassed by the growth of the service's sectors such as construction, tourism and free trade zones (CIA, 2016). The construction industry is one of the sectors that more contributes to the economy's growth in the country (Soler, Salcedo and Núñez, 2013).

Figure 1.1 Location of the Dominican Republic

Source: Mapsland (2015)

The Dominican construction sector has evolved substantially over the past three decades thanks to the low rate loans and mortgages, and the investment from the public and private sector (Department for International Trade, 2015; Banco Central de la Republica Dominicana, 2013; 2014; 2015; 2016; 2017; 2018). Opportunities in this sector comprehend the completion of Santo Domingo underground; construction of the Second phase of Santo Domingo Beltway; construction of civil projects: highways, roads and bridges; construction of hospitals; reconstruction of ports; products and services in the "green building field; urban, regional, transportation planning and project management; and provision of materials (e.g., steel). Potential future projects include a railway project of connecting the cities of Santo Domingo and Santiago; project San Souci District in Santo Domingo; and the development of two international airports (North and Southwestern regions) (Department for International Trade, 2015).

1.1.2 The need for BIM in the Dominican construction industry

Despite showing sustainable and continuous growth, the Dominican construction industry is lacking, in many cases, qualified workforce and innovative and efficient construction techniques (Soler, Salcedo and Núñez, 2013). Other barriers hindering productivity in the sector include the quality of the materials, documenting agreements and procedures, understanding the necessities of internal and external clients, well-defined team focus, and communication between teams (Senior and Rodriguez, 2012). Recommendations to improve this sector include:

- Change technologies used for communication among construction parties;

- Better control of the different subsystems in a construction process;
- Provide construction professionals with technological tools that facilitate the management of the construction process. For instance, the use of tools to reduce the response time, have precise and reliable data and simplify the management and control of different disciplines.
- Dissemination of new technologies that make construction processes more efficient, achieving greater agility in their development, better rationalisation of resources as well as considering environmentally friendly materials. The introduction of these technologies involves a process of change and adaptation of the different methods that take part in the construction of buildings, including the knowledge, abilities, attitudes and activities of the personnel involved (Soler, Salcedo and Núñez, 2013).

In the presence of these needs and due to advent of BIM implementation worldwide and the proven benefits of BIM in this regard, the implementation of BIM comes into view as key to improve current practices and open the way for the digitisation of the Dominican construction industry. Currently, the implementation of BIM in the Dominican construction industry is undocumented, and there are fundamental questions that need to be addressed to understand how the implementation of BIM can be realised. It is against this backdrop that this research has been developed to investigate the status BIM in the country and provide the necessary guidance for the country-wide implementation of BIM in the Dominican construction industry. To bridge the gap in knowledge, the following comprehensive research question has been posited*: What is* *the status of BIM in the Dominican Republic and how country-wide BIM can be realised?*

1.2 Research aim and objectives

The aim of this research is to develop a framework to facilitate the implementation of BIM in the Dominican construction industry. To attain this aim, the following objectives were established:

1. To critically analyse the concept of Building Information Modelling (BIM) and emerging technologies related to its implementation.
2. To investigate BIM global implementation initiatives to identify the critical enabling factors for country-wide BIM implementation.
3. To critically appraise and document the BIM awareness and implementation in the Dominican construction industry.
4. To explore and document the presence of BIM Education in the country.
5. To identify and document the challenges hindering the implementation of BIM in the Dominican construction industry.
6. To develop and validate a framework to facilitate the implementation of BIM in the Dominican construction industry.

1.3 Research questions

To address the aim and objectives of this study, the following research questions were developed:

- What are the prevailing approaches underpinning the implementation of BIM in respect to both process and technology?
- How has BIM been implemented in global construction markets, and what are the critical enabling factors for country-wide BIM implementation?
- What is the status of BIM in the Dominican construction industry in terms of awareness and implementation?
- What is the status of BIM education in the Dominican Republic?
- What are the challenges hindering the implementation of BIM in the Dominican construction industry?
- Which strategies can be set out to propel the implementation of BIM in the Dominican construction industry?

1.4 Methodology

The research methodology for this study is qualitative, which indicates that the research process is primarily inductive. The research process of this study constitutes three phases: research planning, research process and research outcome. The research planning of this study commenced with a preliminary literature review which helped to identify the research problem and formulate the aim and research objectives. A more in-depth literature review was subsequently carried out. The literature review first explored the concept of BIM in the construction industry and the emerging concepts, processes and technologies that have the potential to transform current BIM implementation approaches. Then, it focussed on studying how the implementation of

BIM has been driven in different countries around the world which allowed the identification of the critical enabling factors for country-wide BIM implementation. Theory on research methodologies was reviewed to design the research methodology for this study, which was informed by a pragmatic worldview. The researcher concentrated on what would work best to explore this topic in the Dominican Republic, from which no prior research had been conducted. The lack of research demanded this study to be exploratory; therefore, a qualitative approach was adopted. In line with the qualitative approach, semi-structured interviews were the method selected for the data collection, while content analysis was the method chosen for the data analysis.

The research process consisted of the collection of primary data in the Dominican Republic. The data collection was conducted in two phases: the preliminary study and the main study. The preliminary study allowed the researcher to identify critical issues and evaluate the effectiveness of the adopted methods to make appropriate changes for the main study. The main study represented a more refined process in which key issues were also identified. Research findings encompass, both, findings from the literature review as well as the interpretation of the data collected in the preliminary and main study.

The research outcome represents the consolidation of the research findings through the development of a framework to facilitate the implementation of BIM in the Dominican Republic. Subsequently, the framework was validated with participants of the study. The entire research process is presented in Figure 1.2.

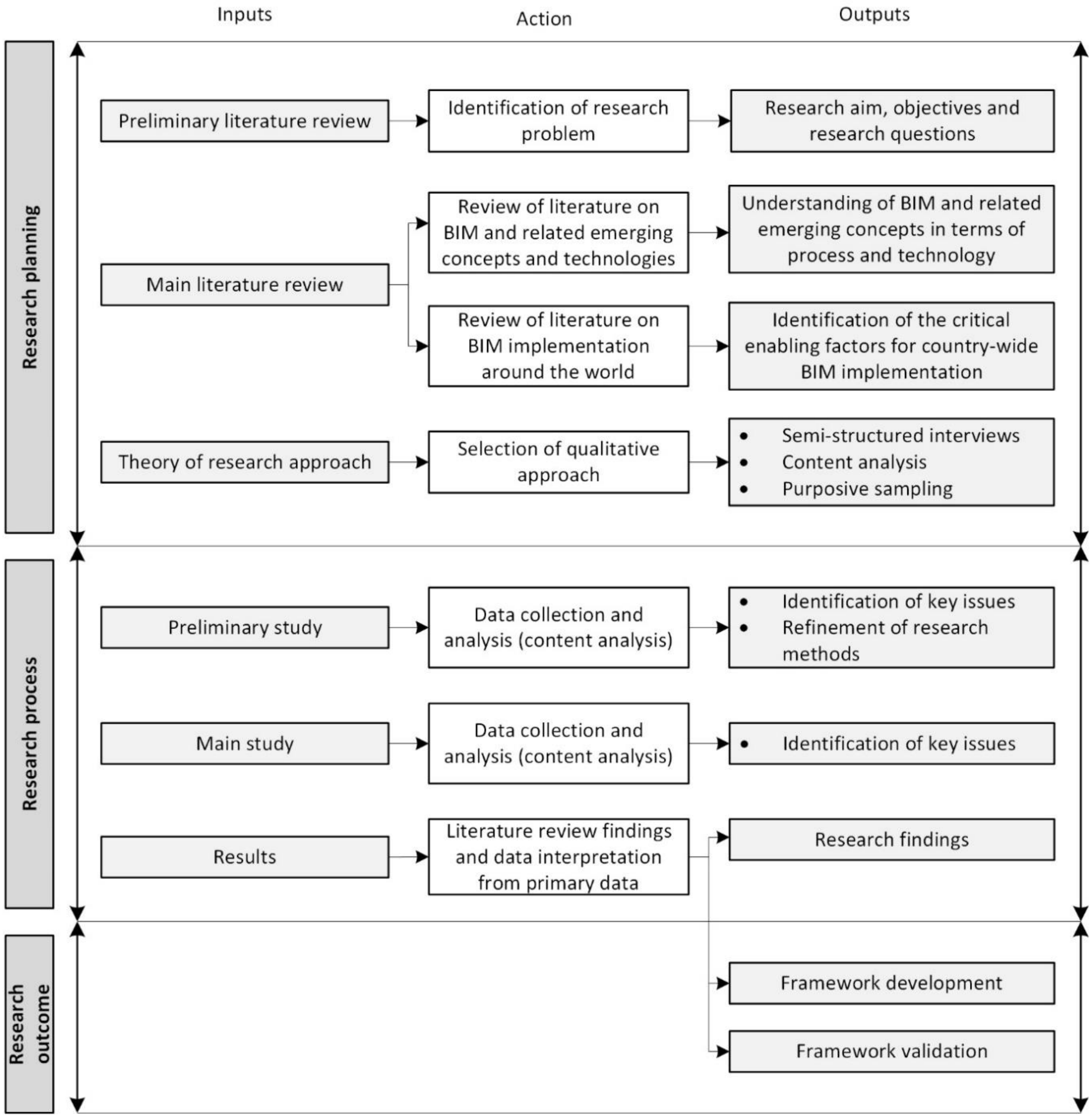


Figure 1.2 Research process

Furthermore, the research methodology adopted allowed this study to fully achieve the research aim and objectives and answer the research questions. Table 1.1 summarises the objectives and their research questions of this study, how the objectives were achieved, and the chapters in which each of them is discussed.

Table 1.1 Correlational table of the objectives, research questions and chapters of the study

Objective (OBJ)	**Research question (R.Q.)**	**How the objectives were achieved**	**Chapters**
OBJ 1: To critically analyse the concept of Building Information Modelling (BIM) and emerging technologies related to its implementation.	RQ1: What are the prevailing approaches underpinning the implementation of BIM in respect to both process and technology?	Literature review on BIM and the emerging concepts, processes and technologies that will impact its implementation.	Chapter 2
OBJ 2: To investigate BIM global implementation initiatives to identify the critical enabling factors for country-wide BIM implementation.	RQ2: How has BIM been implemented in global construction markets, and what are the critical enabling factors for country-wide BIM implementation?	Literature review on BIM implementation around the world focused on early and late BIM adopters. Analysis of the different BIM initiatives and players driving the implementation of BIM to identify the critical enabling factors for country-wide BIM implementation.	Chapter 3
OBJ 3: To critically appraise and document the BIM awareness and BIM implementation in the Dominican Republic construction industry.	RQ3: What is the status of BIM in the Dominican construction industry in terms of awareness and implementation?	Collection of qualitative data through semi-structured interviews from construction organisations. BIM awareness was assessed through the knowledge of the organisations' representatives. On the other hand, BIM implementation was evaluated by the explanation given as to how the construction organisations work.	Chapter 5
OBJ 4: To explore and document the presence of BIM Education in the country.	RQ4: What is the status of BIM education in the Dominican Republic?	Collection of qualitative data from professionals of the construction industry involved in any form of BIM education/training in the country.	Chapter 6
OBJ 5: To identify and document the challenges hindering the	RQ5: What are the challenges hindering the implementation of BIM in	Collection of qualitative data through semi-structured from the interviews directed to	Chapter 7

implementation of BIM in the Dominican construction industry.	the Dominican construction industry?	construction organisations and interviews related to BIM Education.	
OBJ 6: To develop and validate a framework to facilitate the implementation of BIM in the Dominican construction industry.	RQ6: Which strategies can be set out to propel the implementation of BIM in the Dominican construction industry?	Development of a framework to facilitate the implementation of BIM in the Dominican construction industry. The framework was developed from the interpretation of the data analysed in the preliminary and main study, and the literature review undertaken throughout the whole research.	Chapter 8

1.5 Scope and limitations of this research

The focus of this research is to study the status of BIM in the Dominican construction industry. In pursuing this aim, it was considered necessary to approach construction organisations in the country through their representatives to evaluate the BIM awareness and BIM implementation as specified in the third objective of this research (Refer to Section 1.2 and Table 1.1). The research includes both private and public sector organisations that work with different construction tasks (design, construction, supervision, etc.) and develop different types of facilities (residential, commercial, etc.). Also, the status of BIM Education in the country was explored, as stated in the fifth objective of this research (Refer to Section 1.2 and Table 1.1), due to its essential role in preparing and motivating professionals to implement BIM. For that purpose, professionals of the construction industry involved in any mode of education/training on BIM in the country took part in the study.

Given the scope of the study, it is also important to state its limitations to understand the reasons why other potential participants and type of analysis were not considered:

- This study did not include the evaluation of current BIM practices in the country through construction projects. This approach was contemplated at the beginning of the research journey but was discarded due to the scarcity of projects implementing BIM in the country.
- This research did not consider information from the organisations such as their sizes or way of working as part of the data analysis since this type of information would not have a relevant contribution to the objectives and research questions posed for this study.
- Government authorities and policymakers of the Dominican construction industry (e.g., City Councils, Ministries) did not take part in this research. Currently, there are initiatives from the government to drive digitalisation in the country, but none of them is related to BIM implementation. The few manifestations of BIM in the country were initially identified from players within the construction industry (Despradel, 2015) (Refer to Chapter 3, Section 3.5) and later from the field of education and training (Refer to Chapter 7, Section 7.2). Therefore, this research has included only the participation of construction organisations and professionals involved with BIM Education and Training in the country. It is important to point out that the results of this study (the framework) suggested the involvement of the government to attain country-wide BIM implementation. Hence, recommendations for the government have been provided (Section 9.6.2)

and further studies with the participation of Dominican governmental entities have been suggested (Section 9.6.3).

- The framework is directed to the D.R. because it was developed from context-specific data.

The limitations presented above do not intend to undermine this research but to accurately define its boundaries. Furthermore, they provide possible scenarios for other researchers to undertake another type of research that can follow this research study. Recommendations on this regard are posited in Chapter 9, Section 9.6.

1.6 Structure of the thesis

The structure of the thesis is illustrated in Figure 1.3. This thesis is arranged logically and consistently, starting with the Introduction to the research in Chapter One and finishing with the Conclusions and Recommendations in Chapter Nine.

Chapter Two presents a review of literature on Building Information Modelling (BIM). First, a brief history of BIM is provided. Then, the concept of BIM is explained along with important aspects related to the implementation such as BIM dimensions, BIM maturity levels and the concept of OpenBIM. Lastly, the chapter seeks to highlight the most relevant emerging concepts, processes and technologies with the potential of changing and improving the current implementation of BIM. BIM is a crucial component of digitalisation and the concept of Industry 4.0. Therefore, this section first introduces the concept of Industry 4.0 and concisely discusses other essential concepts and technologies, namely blockchain, Internet of Things (IoT), Big data, Digital Twin and

Artificial Intelligence. The importance of open standards to implement digital technologies in the construction industry is also emphasised.

Chapter Three continues the review of the literature but focuses on the implementation of BIM worldwide. The chapter first discusses the implementation of BIM in early BIM adopter countries which are current leaders of BIM worldwide, specifically United States of America; Finland, Denmark, Norway and the United Kingdom from Europe; and Singapore from Asia. Then, it covers the implementation of BIM in late BIM adopter countries, namely Hong Kong and China from Asia; and Brazil, Chile and Mexico from Latin America. The chapter seeks to point out the most relevant initiatives and players that have enabled the implementation of BIM in those countries, and subsequently identifies the critical enabling factors for country-wide BIM implementation, which are Central government/public sector leadership, Academia leadership, Industry leadership and Global BIM influence. Lastly, since the focus of this study is the implementation of BIM in the D.R., an overview of what is currently known about BIM in the D.R. is provided.

Chapter Four outlines in detail the research methodology adopted for this study; in this case, a qualitative research design has been adopted. This chapter discusses the selection and justification of the different elements that constitute this research. The research strategy is extensively explained, providing information about the need for a preliminary study, sampling considerations and data analysis process. Lastly, a description of the phases of the research process, namely, the preliminary study and the main study is provided.

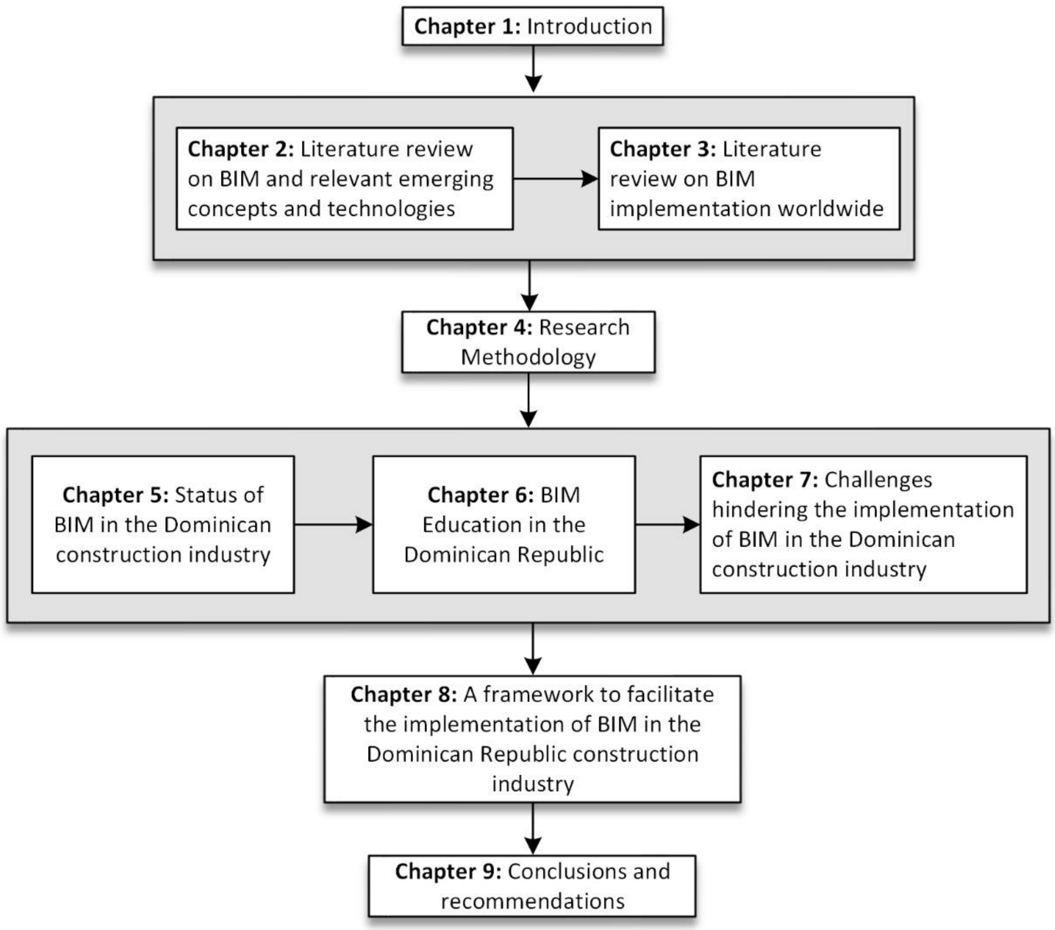


Figure 1.3 Structure of the thesis

Chapter Five presents the analysis of the data collected from the interviews directed to construction organisations conducted in the preliminary study and the main study. The chapter presents the BIM awareness among the participants. Then, it discusses the analysis of the status of BIM implementation in these organisations. For this analysis, participant organisations were classified into three categories: organisations that do not implement BIM, organisations in transition to implementing BIM and organisations implementing BIM.

Chapter Six presents the analysis of the data collected from the interviews related to BIM education conducted in the main study. This analysis allowed the description of the status of BIM Education in the country.

Chapter Seven presents the analysis of the data collected from the interviews directed to construction organisations and related to BIM education in the main study. The chapter discusses the challenges hindering the implementation of BIM in the Dominican construction industry from the perception of the interviewees.

Chapter Eight presents the interpretation of the entire data collected in the research and how it influenced the development of the framework for implementing BIM in the Dominican construction industry. It provides a thorough explanation of the components of the framework. It also discusses the validation of the framework.

Chapter Nine presents how the research objectives have been attained in this study. It discusses the key findings, beneficiaries of this research, and the contribution to the body of knowledge. Lastly, it provides recommendations and offers direction for further studies.

CHAPTER 2: LITERATURE REVIEW ON BUILDING INFORMATION MODELLING AND RELEVANT EMERGING CONCEPTS, PROCESSES AND TECHNOLOGIES

2.1 Introduction

This chapter aims to address the first objective of this research which is *"To critically analyse the concept of Building Information Modelling (BIM) and emerging technologies related to its implementation".* This chapter starts by introducing the history of BIM in the construction industry. Then, it discusses what BIM is and provides relevant information related to the implementation of BIM such as BIM dimensions, BIM maturity levels and the concept of OpenBIM. Then, it focuses on the study of emerging concepts, processes and technologies related to BIM: Industry 4.0, Blockchain, Internet of Things, Big data, Digital Twin and Artificial Intelligence. Lastly, it discusses the importance of open standards to enable information sharing among all these technological advancements.

2.2 Introduction to Building Information Modelling

The concept of BIM, in particular, building description systems, was first introduced by Eastman (1976) in the mid-1970s as a 'database capable of describing buildings at a detail allowing design and construction'. This notion encompasses parametric design, generating two-dimensional (2D) drawings from a model, and a 'single integrated database for visual and qualitative analysis, which gives benefits for contractors of large projects on scheduling and material procurement. This method was later defined as 'building product models' in the United States and 'production information models' in Europe, both terms focusing on "product" not on "processes" (Li *et al.*, 2017). The term, in the sense it is used today, was first used in van Nederveen's 1992 paper "Modelling multiple views on buildings" (Won *et al.*, 2013).

Since the early 2000s, BIM has been considered as a method to transform the labour-intensive and inefficient practices in the construction industry (Sacks *et al.*, 2018). The use of BIM started to increase after the construction industry analyst Jerry Laiserin argued in 2002 that BIM should be an industry-standard term. The term also caught the attention of Autodesk, which started promoting it widely within their products (Ghaffarianhoseini *et al.*, 2017).

Due to the importance of BIM in the construction industry nowadays, there are multiple definitions of BIM available in the literature. This research has adopted the definition developed by Succar (2009): *"a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building life cycle".* BIM can be seen as a virtual process that includes all the aspects, disciplines and systems of a project embedded in a single, virtual model that enables all participants of a project (architects, engineers, contractors, subcontractors, suppliers and clients) to collaborate more effectively and accurately than traditional practices. While the model is being developed, project members are regularly improving and making changes in their areas of work conforming to project specifications to ensure the accuracy of the model before it is physically constructed. BIM is a combination of process and software. BIM requires not only the use of an intelligent model but also essential changes in the workflow and project delivery processes (Azhar, 2011).

BIM can be potentially used at all stages of the project life-cycle, from initial design stages through construction to operation and eventually demolition (Eadie *et al.*, 2013a; Ghaffarianhoseini *et al.*, 2017) (Refer to Figure 2.1).

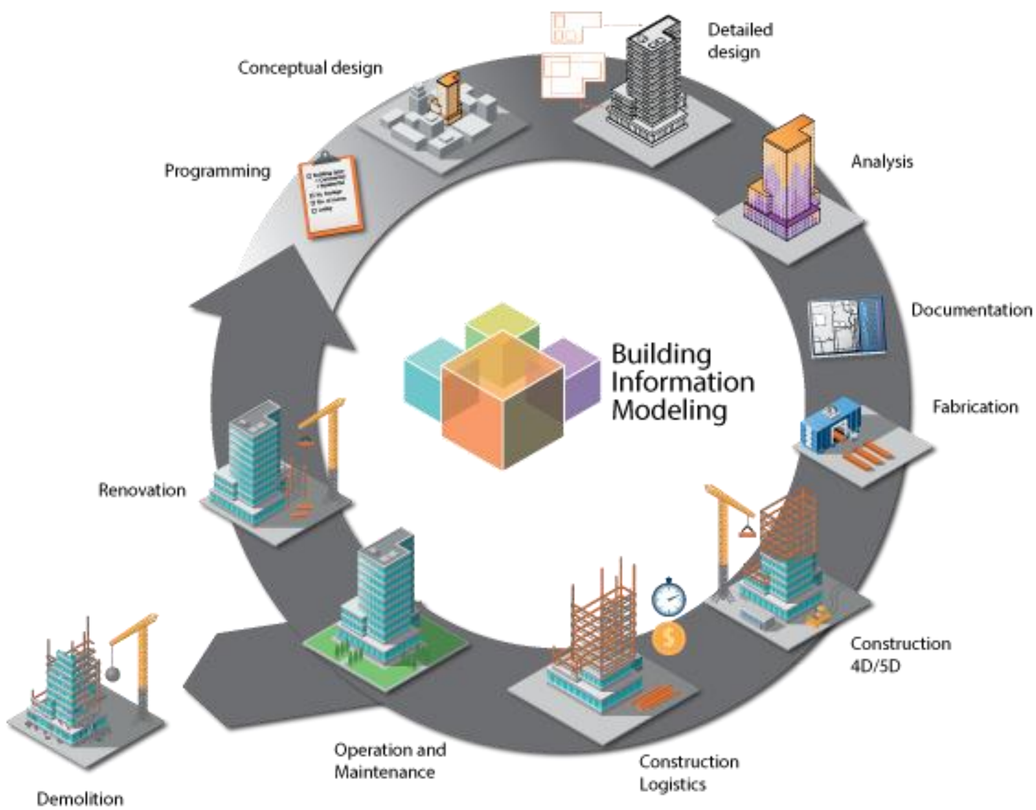


Figure 2.1 Use of BIM in different stages of the project's lifecycle

Source: The BIM Hub (2016)

BIM covers design, construction and management applications. BIM is currently being implemented in construction inter-organisational design coordination, automatic detection of design-related errors, automated building design review, construction safety management, identification and prevention of hazards, and construction risk management (Ghaffarianhoseini *et al.*, 2017). In terms of project actors, BIM can be used by owners to understand project's needs; by the design team to analyse, design and develop the project; by contractors to manage the construction of the project; and by facility managers throughout the operation and decommissioning phases (Bryde *et al.*, 2013).

BIM facilitates a new method of working by providing a common environment in which all the information of a building or asset is stored, along with its components and activities (Merschbrock and Munkvold, 2015). As a collaborative technology, BIM offers the construction industry an opportunity for integration and is perceived as a feasible response to the communication-related issues related to the industry (Mahamadu *et al.*, 2017).

2.2.1 BIM dimensions

BIM dimensions can be defined as the building information that might be required to be embedded in a model. At first, this denoted the difference between 2-D computer-aided design (CAD) information and 3-D dimensional information from BIM models. However, it has spread to incorporate another type of information that might be necessary to manage the design, construction and operation of built assets (BIM Wiki, 2018a).

Currently, there is not a consensus of what BIM dimensions involved, which has resulted in different classifications and definitions: 3D to 6D by the NBS (McPartland, 2017); 2D to 6D (BIM Wiki, 2018a); 1D to 7D (Saxon, 2018); 3D to 8D (Smith, 2014). Furthermore, the multidimensional capacity of BIM has been coined with the term 'nD' modelling, referring to the capacity of adding practically an infinite number of dimensions to the Building Model (Smith, 2014a).

Following the definition of BIM dimensions and having analysed the different classifications that exist, this study adopted the classification from 3D to 6D by the NBS as it comprehends the essential data that needs to be linked to a BIM model:

- *3D* is possibly the most common dimension of BIM. 3D is the shared information model. It comprehends the creation of graphical (2D and 3D) and non-graphical information which is to be shared with the project team in a Common Data Environment (McPartland, 2017). The 3D model offers important benefits for the project, such as model walkthroughs, clash detection, project visualisation, virtual mock-up models and prefabrication (BIM Talk, 2013).
- *4D* refers to time and programme information (BIM Wiki, 2018a) which is the responsibility of the project manager and contractor (Saxon, 2018). Data is added to elements which will be built and can be used to get exact programme information and visualisations of how the project will be developed in sequence (McPartland, 2017). Thanks to this dimension, more robust schedules and site layout and logistics can be developed to enhance productivity (Smith, 2014a).

- *5D* refers to cost information (BIM Wiki, 2018a) and is within the domain of the cost consultant (Saxon, 2018). The 5D model allows the instant generation of costs budget and accurate financial representations of the model against time. Benefits include the reduction of the time needed for quantity take-off and estimation and the accuracy of cost estimation. A 5D model also reduces disagreements generated from the ambiguities in CAD data and enables cost consultants to spend more time on value improvement (Smith, 2014a).
- *6D* refers to the facilities management information (BIM Wiki, 2018a), which is related to the building owner and their facility and asset managers (Saxon, 2018). This dimension is often named as integrated BIM or iBIM. 6D BIM consists of including information to assist facilities management and operation. Data might include information on the manufacture of an element, its installation date, required maintenance, and specifications on how the element should be configured and operated for best performance, energy performance as well as lifespan and decommissioning data (McPartland, 2017). Through data capture, sensors can feedback and document essential data for the operation of the building, allowing BIM to model and evaluate energy efficiency, monitor lifecycle costs of the building, and improves its cost efficiency (BIM Talk, 2013).

2.2.2 BIM maturity levels

BIM maturity is an essential term in the context of BIM implementation. BIM maturity refers to the degree of progression of BIM use (Jung and Joo, 2011). Succar and

Kassem (2015) further explained that *BIM maturity or post-implementation* is the progressive and consistent enhancement in quality, repeatability and probability in available competencies. BIM maturity denotes the maturity levels or performance improvement indicators that organisations, teams and whole markets aim to achieve.

Two BIM maturity models have been widely used to explain and clarify BIM maturity: the Bew-Richards BIM maturity model and the BIM maturity stages by Bilal Succar. Both models were conceived by studying the natural maturity that has already occurred and predicting future practical implementations of BIM and associated techniques (Jayasena and Weddikkara, 2013).

2.2.2.1 Bew and Richards' BIM maturity levels

The BIM maturity model developed by Bew and Richards is considered as one of the most relevant contributions resulted from the UK BIM activities (RICS, 2014). It is the most used model when discussing the BIM maturity either in a market or an organisation (Jayasena and Weddikkara, 2013). It uses the term 'BIM levels' to describe which criteria are needed to be considered BIM-compliant and has been defined from 0 to 3 (NBS, 2014) (Refer to Figure 2.2):

- **Level 0:** Use of 2D CAD drafting only, primarily for production information, which is the way of work implemented by many years in design. It is characterised for the absence of collaboration.

- **Level 1:** It is a mixture of 2D and 3D information. 2D is used for product information and drafting of legal approval documentation. Models are used only for visualisation purposes. There is the use of CAD standards and a Common Data Environment for collaborative work (NBS, 2014).

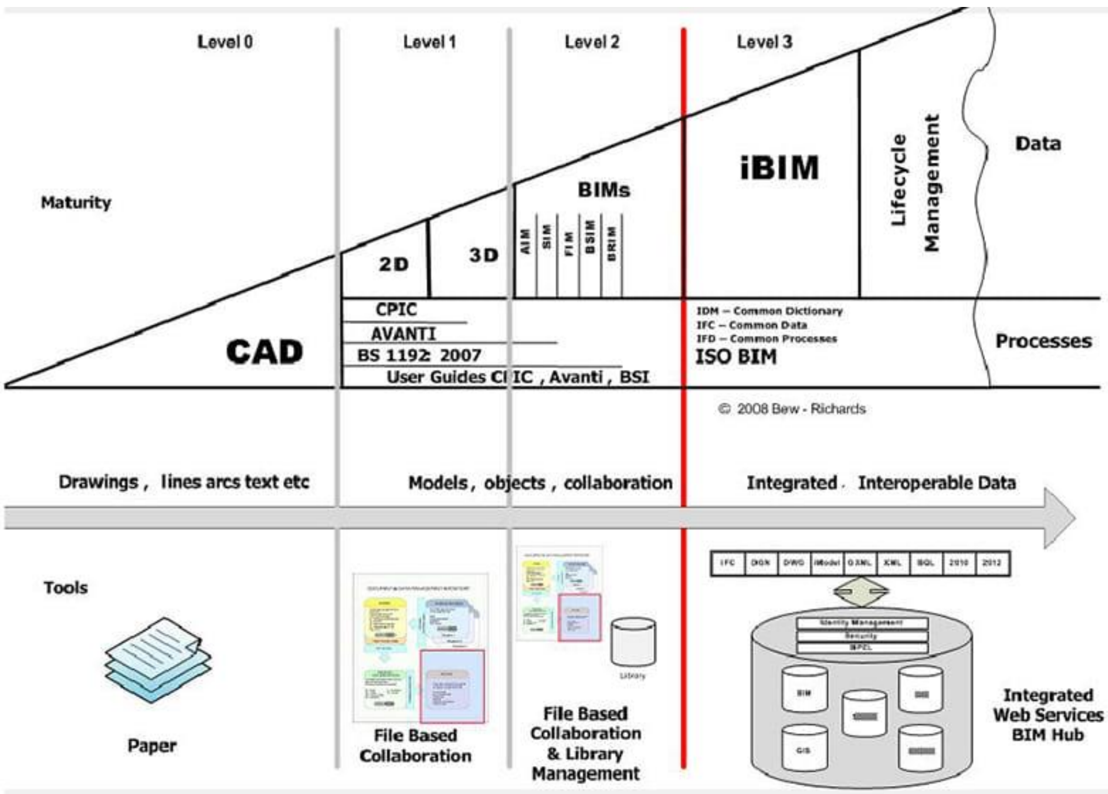


Figure 2.2 BIM Levels by Bew and Richards

Source: Mordue (2019)

- **Level 2:** This is the method set as the minimum by the UK government BIM mandate from 2016 (Refer to Chapter 3, Section 3.2.3). It is characterised by collaborative working, “collaborative BIM”, and demands the coordinated exchange of information between various disciplines and project members. A federated model is created containing all the information of the project, which needs to be shared in the Common Data Environment (CDE). Any software used must allow the export to one the common formats such as IFC (Industry Foundation Classes) or COBie (Construction Operations Building Information Exchange) (NBS, 2014; Mordue, 2019).

- **Level 3:** Literature shows two meanings of this level. Level 3 BIM consists of the full collaboration between all disciplines involved in a project through the use of a single shared project model that is kept in a centralised repository, which is usually an object database in the cloud. That allows all the members of the project to have access and make changes to the same model. That is also known by many as OpenBIM (Sacks *et al.,* 2018), a concept that is explained in Section 2.2.3.

Level 3 BIM has also been described under the phrase Digital Built Britain (DBB) in the UK (BIM Wiki, 2019c). DBB was initially launched in 2015 and re-launched in 2016 and is built on the achievement of BIM level 2 programme. It will allow the interconnected digital design of different elements in a built environment and spread the use of BIM into the operational phase of assets, where the cost increases. DBB will also encourage the increased dissemination of smart cities, services and grids. It will enable owners and operators to manage assets and services in a better way since they will be able to monitor their real-time efficiency which subsequently will maximise utilisation and decrease energy use (Bew, 2017). Bew (2015) indicated that Level 3 BIM was a 10-year plan, starting in 2017-18, which consisted of five years of preparation and five years of implementation and development of early adopter projects. It is predicted that by the next decade BIM will be integrated with the internet of things (IoT), advanced data analytics and the digital economy, which will enable more efficient planning, build at a lower cost and better operate assets (BIM Wiki, 2019c). Some of these important concepts that will enable Level 3 BIM are explained in Section 2.3.

2.2.2.2 Succar's BIM maturity stages

Through the BIM maturity stages, Succar (2009) developed a systematic way to understand the BIM maturity within organisations, projects and industry. The BIM maturity stages present a series of stages that stakeholders need to implement gradually and sequentially. As depicted in Figure 2.3, the starting point is the status of the industry before BIM implementation; then it illustrates the BIM maturity levels which are subdivided into three stages; lastly, a variable ending point presents an unpredicted scenario of future advancements in technology.

Figure 2.3 BIM maturity stages

Source: Succar (2009)

- **Pre-BIM** represents traditional construction practices which are affected by significant barriers. It is mainly based on 2D documentation. 3D visualisations can be created but are usually disconnected and depend on 2D documentation and detailing. Furthermore, quantity take-off, cost estimates and specifications are not linked to the models or the documentation. Collaboration between project members is not sought, and workflows are linear and asynchronous.

- **BIM Stage 1** is the transition from 2D to 3D and object-based modelling and documentation. Single disciplinary models are created mainly for 2D documentation and visualisation. The collaboration is similar to pre-BIM status, and there are not relevant model-based exchanges between disciplines. Contractual relations and responsibility issues continue.
- **BIM Stage 2** represents the progress from modelling to collaboration and interoperability. Project members collaborate in a multi-disciplinary manner through BIM software tools. The model-based collaboration can be either by the interchange of models using proprietary formats or the interchange of models using non-proprietary formats, where the use of an IFC file format is needed. Communication among stakeholders is not synchronised yet. However, the separation of roles, disciplines and lifecycle phases typical of the pre-BIM start to disappear. Due to the increase of model-based interchanges, some contractual amendments start to be indispensable (Succar, 2009; Khosrowshahi and Arayici, 2012).
- **BIM Stage 3** is the transition from collaboration to integration. Semantically-rich integrated models are produced, shared and kept throughout the project lifecycle phases. Models at this stage turn into interdisciplinary nD models which can

perform analysis at early phases of virtual design and construction. Model deliverables include not only semantic object properties but also business intelligence, green policies, lean construction principles, and complete life cycle costing. The collaboration process is done through a comprehensive, united and sharable data model. Project members can interact in real-time through virtual workflows (Succar, 2009; Khosrowshahi and Arayici, 2012).

- **Integrated Project Delivery (IPD)** is a denomination used to describe the long-term vision of BIM as a merge of processes, policies and domain technologies. IPD is a project delivery method where people, business structures, practices and systems are combined into a process that manages the attitudes and perceptions of all the members together. IPD seeks to get better project results, increment value to the owner, minimise waste and increase the effectiveness in all the stages of design, fabrication and construction (Succar, 2009).

The aspects discussed above have been introduced to understand the BIM maturity level of some of the studied countries in Chapter 3 (i.e. the United Kingdom). They have also been considered for the framework developed in this study (Chapter 8).

2.2.3 OpenBIM

The growing interest in BIM, as well as the problems of lack of interoperability between BIM software, has engendered the need to establish a universal means for data exchange between different disciplines and efficient management of large amounts of data. To address this issue, the buildingSMART alliance created the OpenBIM approach built on open standards and formats (Rahimian *et al.*, 2019). OpenBIM is *"a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows"* (BIM Wiki, 2016). OpenBIM provides significant benefits to AEC (Architecture, Engineering and Construction) professionals:

- Project participants can work with state-of-the-art software within their field without having the uncertainty of being excluded from a BIM project.
- Project participants can keep full control over software upgrades, independently from their teammates.
- Workflow integration leads to reduced coordination mistakes in contrast to sheer file compatibility of several software tools.
- BIM data is available throughout the whole project lifecycle, including construction and operation, thanks to the use of open standards.

OpenBIM also offers significant benefits to AEC building projects. If a digital building model is developed with an OpenBIM approach, future owners, tenants and operators will be provided with better options to use data from this model further. That also contributes to an increased ROI (Return of Investment) throughout the building life cycle (Graphisoft, 2019).

BuildingSMART has the responsibility of developing and maintaining OpenBIM standards. Various of these standards have been followed by the ISO (International

Organization for Standardization) and CEN (European Committee for Standardization). The main buildingSMART standard is the Industry Foundation Classes (IFC) (ISO 16739), from which other buildingSMART are built on and from which OpenBIM exchange processes take place (Baldwin, 2019).

OpenBIM has the power to support industry development and innovation to a great extent (Granholm, 2019). Furthermore, it is alleged that standards for data transfer to facilitate OpenBIM are necessary to drive competitiveness and the concept of Industry 4.0 within the construction industry (FIEC, 2017).

2.3 Emerging concepts, processes and technologies related to BIM

BIM is a component of the whole digitisation of the construction industry and the concept of Industry 4.0 (FIEC, 2017). Industry 4.0 has opened the way for digital technologies in the construction industry such as intelligent machines, smart materials and sensor systems in which BIM serves as the central repository to collect and store digital information about a project. BIM offers an excellent platform for the development of cutting-edge and powerful applications for the construction industry by enabling an extra layer of data to communicate and collaborate in real-time during the project life cycle (Maskuriy *et al.*, 2019). Moreover, BIM and associated technological innovations can encourage more transparency, closer integration and improved productivity in the construction industry (Merschbrock and Munkvold, 2015).

This section intends to discuss important emerging concepts, processes and technologies which are transforming the construction industry along with Building Information Modelling, namely, Industry 4.0, Blockchain (smart contracts), Internet of Things, Big Data, Digital Twin and Artificial Intelligence (machine learning). These are briefly explained, highlighting the benefits and challenges of their adoption and their relation and future opportunities with BIM.

2.3.1 Industry 4.0

Industry 4.0 is a term developed by the German Federal Government to encourage its High-Tech strategy. This multilayered term has been mostly used in diverse contexts in popular science and contains an array of ambiguous interdisciplinary concepts. It has been usually considered a synonym for the planned Fourth Industrial Revolution by indicating its tremendous technological power, similar to the technical innovations which were introduced in previous industrial revolutions: (1) the field of mechanisation, (2) the use of electricity, (3) the starting point of digitisation (Oesterreich and Teuteberg 2016). Industry 4.0 has also received the names of "Industry Revolution (IR) 4", "Smart Manufacturing", "Smart Production" and "Industrial Internet" (Oesterreich and Teuteberg, 2016; Alaloul *et al.*, 2018; Woodhead, Stephenson and Morrey, 2018).

Industry 4.0 enables computerisation and inter-connection into the traditional industry. It produces disruptive changes to business models, business processes and supply chains. The principles of Industry 4.0 include decentralisation, interoperability, real-time capability, modularity, service orientation and virtualisation (Lu, 2017). These principles are also related to what the UK is aiming to achieve with Level 3 BIM (Refer to Section 2.2.2.1).

2.3.1.1 Industry 4.0 and the construction industry

In the construction industry context, Oesterreich and Teuteberg (2016) defined Industry 4.0 as a broad field of concepts and interdisciplinary technologies that facilitate the integration, automatisation and digitisation of the construction process. The term can also be used as a synonym to explain the growing implementation of ICT (Information and Communications Technology) and other manufacturing technologies.

Industry 4.0 will unquestionably impact the future of the construction industry as it represents development on three crucial aspects:

- Digitisation of production: data systems for organisations and construction preparation.
- Automatisation: Systems for the acquisition of information from the construction site and further machines usage.
- Linking construction sites to a supply chain: extensive automatic information exchange (Alaloul *et al.*, 2018).

As per Oesterreich and Teuteberg (2016), the key Industry 4.0 technologies and concepts within the construction industry can be grouped into three categories: Smart Factory, Simulation and modelling, and Digitisation and virtualisation (Refer to Figure 2.4).

Smart Factory	**Simulation and modelling**	**Digitisation and virtualisation**
•Cyber-Physycal systems/Embedded systems/Radio-frequency identification (RFID) •Internet of Things/Internet of Services •Automatisations •Modularisation/Prefabrication •Additive Manufacturing •Product-Lifecylce-Management (PLM) •Robotics •Human-Computer Interaction (HCI)	•Simulation tools/Simulation models •Building Information Modelling •Augmented Reality (AR)/Virtual Reality (VR)/Mixed Reality (MR)	•Cloud Computing •Big Data •Mobile Computing •Social Media Digitisation •Digitisation

Figure 2.4 Key technologies and concepts of Industry 4.0 in the construction industry

Adapted from Oesterreich and Teuteberg (2016)

By adopting the concept of Industry 4.0, the construction industry can transform to a technology-driven industry and keep up to date with other manufacturing industries which are currently more advanced than the construction industry regarding performance enhancement (Oesterreich and Teuteberg, 2016).

2.3.1.2 Industry 4.0 and BIM

At present, BIM is seen as the main technology for the digitisation of the construction manufacturing environment and can be acknowledged as one of the main technologies to support the core idea of Industry 4.0 (Oesterreich and Teuteberg, 2016; Dallasega, Rauch and Linder, 2018). Key components of Industry 4.0 namely, Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services, big data, Artificial Intelligence (AI), and smart production applications have the potential to improve the implementation of BIM in the construction phase. Waste management operation is enhanced, which, therefore, raises productivity. BIM potential is increased by supervising the operation of the project, overseeing the workers using the BIM model, controlling material manipulation and separating waste on-site. Although these opportunities have been identified, it is necessary to conduct more studies in the area to integrate BIM with Industry 4.0 (Maskuriy *et al.*, 2019).

2.3.2 Blockchain

Blockchain (BC) is a digitised, decentralised public ledger of assets, data and any other relevant transaction that has been performed and shared among parties within the same network. Blockchain was first implemented in Bitcoin, the world's first cryptocurrency to be widely used, which was introduced in 2008. A bitcoin is an exchangeable asset generated by the blockchain system as a method of payment for its operation and maintenance by miners. Despite being related to cryptocurrencies, blockchain is seen as a developing technology that could probably change and reform the existing digital operational activities and business practices of computing, government services, finance and virtually every single current industry. The central premise of blockchain is the development of a digital distributed consensus, making sure that data is decentralised between several nodes that contain exact information and that no one has the total control of the network. This workflow allows transparency and improves data security (Nawari and Ravindran, 2019).

Nowadays, the term blockchain has become the synonym of Distributed ledger technology (DLT), and both terms are used interchangeably (Li *et al.*, 2019). Nonetheless, Distributed ledgers are one of the main characteristics of blockchain. DLT network works by disseminating the computational workload across several nodes in a network which can make independent decisions as opposed to the case of a centralised ledger network in which a single central point is responsible for managing and controlling information and operational power. DLT usually integrates a decentralised consensus system in which all the approved nodes in the system run the same consensus algorithm that has been established. This feature removes the need for an intermediary party to authorise transactions, which is fundamental in blockchain technology (Nawari and Ravidran, 2019).

BC integrates the economic incentive and cryptographic link between records and the distribution of the data on a decentralised network which is accessible to all the members that belong to a node system. Since all the members have access to the same information, it is difficult to change any node. The longer the chain is, the more difficult it is. Therefore, a hacker would need to have access to a large amount of computational power to cause significant damage to the information (ARUP, 2019).

2.3.2.1 Blockchain in the built environment

Blockchain technologies have not been revolutionary for the built environment yet. Nonetheless, initial use cases in the cities, energy and transport markets are demonstrating their potential. Experts predict that early adoption may start from 2020-

2025. Blockchain technology has the power to revolutionise the built environment by establishing a new basis where machines can interact and transact with each other. Blockchain could improve transparency in supply chains and offer the technological basis required to integrate aspects of BIM, IoT systems, smart sensors and circular economy in the built environment.

There have been identified three phases of blockchain technologies in the built environment. The first phase of blockchain has consisted in the automation of payments and transactions. The second and third phase are predicted to be more intricate, allowing the enhancement of transactional effectiveness and reliability, data management and governance (ARUP, 2019).

Blockchain application in the built environment can be categorised into the following: Smart Energy; Smart cities and sharing economy; Smart government; Smart Homes; Intelligent Transport; Building Information Modelling (BIM) and Construction Management; and Business Models and Organisational Structures (Li *et al.*, 2019).

2.3.2.2 Blockchain in the construction industry

Blockchain is considered to have the power to change many universal sectors, including the construction industry (Li *et al.*, 2019). Thus far, its use in this sector has been limited. BC is being used to store sensor data from buildings in a reliable and dispersed way. Other applications of blockchain comprehend keeping records of digital property, timestamping acts or transactions, multi-signature transactions, smart contracts and smart oracles. Using blockchain in real estate investment and automated dispute resolutions has also been envisaged (Turk and Klinc, 2017).

For the construction industry, the key use of blockchain is in the automation of transactions and on cash flow management. Blockchain technology can be used to enable automatic payments and transactions among parties and pay contractors and subcontractors for the work done. It can also be used to maintain a retainer and release the partial payment. The requisites of the contract and payment timetable can be established in advance.

Companies can experience cash flow issues for a variety of reasons. Nonetheless, when an agreement is recorded with blockchain, the selected controlling body is set at the beginning to enable an impartial and reliable system. When the work is finished, all transactions are approved by a community which can avoid the presence of several intermediaries.

Thanks to the decentralised system of blockchain, the funds are centrally controlled and released when the work is confirmed. That could avoid clients retaining funds from contractors and, in turn, contractors keeping funds from subcontractors, hence allowing better cash flow (ARUP, 2019).

Blockchain can assist in the development of a record containing past accomplishments and qualifications of project team members. This record can be used later to make comparisons among team members; thus facilitating decision-making processes for project managers and clients to choose a multipurpose and well-proportioned team with diverse expertise and experience (Nawari and Ravindran, 2019).

2.3.2.3 Blockchain and BIM

BIM workflow is built on a centralised database, especially cloud-based, which can be affected by security and accessibility problems such as wrapping attack, online cyber theft, malware injection, etc. There is also the risk of bringing down the quality and integrity of the data transactions. The use and integration of blockchain in a BIM workflow could deal with some of these current problems and suggests new areas of application (Nawari and Ravindran, 2019). Blockchain can solve some issues that hinder the use of BIM in the industry such as confidentiality, multi-party aggregation, disintermediation, traceability, data ownership, inter-organisational recordkeeping, change tracing, non-repudiation, etc. (Turk and Klinc, 2017).

The use of an immutable digital ledger facilitates the mapping and tracking of a project at every phase. In the design phase, this is advantageous to set up ownership of models and record enhancements and modifications. In the operational phase, a BIM blockchain-aided virtualisation can be connected to its physical entity, with changes tracked internally (ARUP, 2019). In terms of collaboration, the transparency of blockchain integrated with the database characteristics of BIM can offer *evidence of trust* that stakeholders can use to come to an agreement. This collaborative culture change can solve problems of unclear liabilities and responsibilities by giving priority to collaboration and share risks and rewards among the parties. Moreover, this evidence of trust can be a powerful and reliable element for collaborative design processes, and Integrated Project Delivery (IPD) approaches.

Despite there are fewer trust problems in a BIM environment compared to traditional methods, the complexity of the BIM framework generates security issues related to information stealing, data leakage and information protection while negotiating. The removal of an intermediary to supervise transactions in a blockchain network improves the cybersecurity levels of current systems significantly. Blockchain networks guarantee that no single node in the network has total access to all the information (Nawari and Ravindran, 2019).

Lastly, blockchain could speed up the progress towards BIM level 3, in which all participants work together on a single, collaborative, shared model, by allowing better levels of security, reliability and live data gathering in an open and reliable environment. Blockchain could also offer an unchangeable record of modifications, demonstrating ownership of a model or digital element and decentralised common data environments (ARUP, 2019).

2.3.2.4 Challenges and risks of implementing blockchain

To date, the understanding of blockchain in the industry is limited; therefore, there is a risk in trying a new technology without having enough knowledge about the problems that blockchain can resolve. Moreover, blockchain technologies still have some scalability problems which make them slower and more incompetent than conventional databases.

Blockchain has inherent new challenges with more insecurity weaknesses and a broader network economy that have never existed before. Blockchain works well in an open world; hence, it is important to be cautious with the data that is added to a blockchain. This way, delicate information is not leaked, and the possibility of attacks is diminished. The trust system of blockchain is based on the supposition that private keys cannot be stolen or hacked. However, this has motivated hackers to find clever ways to crack codes (ARUP, 2019).

Li *et al.* (2019) argued that the benefit of eliminating intermediaries from supply chain might result in the extinction of some industry players. They further pointed out other key challenges to the use of blockchain in the construction industry:

- The cost of implementation since each component or building system would require an IoT enabled device. This cost can, therefore, affect its adoption rate.
- Developers of relevant technology not considering the construction industry, which may result in a substantial time lag.
- The construction industry lags behind in adopting new technologies.
- Limited knowledge and understanding of the benefits DLT/blockchain offer to the construction industry. The diffusion of knowledge represents further challenges.

Furthermore, blockchain applications are not exempts of risks as they are still vulnerable to different types of security problems. Some of these risks include:

- **Double payments**: There is the possibility that two parallel transactions transfer the same data to different receivers which generates a new but unacceptable transaction. To avoid this, a Proof of Work (PoW) consensus can be imposed in which all parties agree about the order of transactions that have been executed.
- **51% attacks**: If a participant dominates 51% of the network, he/she does have a huge chance of interfering with the blockchain with no repercussions because of having more power to impose consensus. That makes smaller networks more vulnerable to attacks because one participant can be more control in the blockchain at the beginning.
- **Involuntary centralisation**: The participants in the blockchain network impose security. Therefore, there is no way to stop the weakest participants from transferring data to a centralised system of exchange. A case in which this occurs is when a third party has cumulated multiple assets and is storing them for other users. Additionally, assets in pure blockchains can be centralised in agreement.
- **Absence of privacy due to the pseudonymity of users**: It is important to decide which information needs to be private and which information can be available for the public. Also, it is not possible to attain total privacy because one

participant can deduce the data of another participant by scrutinising their transactions movements.

- **Data flexibility**: It is impossible to assure the integrity of the digital signatures that are used to authorise transactions. In such a situation, a hacker, for instance, would interrupt a transaction to modify it and transfer it to the network (Nawari and Ravindran, 2019).

2.3.2.5 Smart contracts

Smart contracts are possibly one of the most significant aspects of blockchain in the construction industry (Li *et al.*, 2019). They emerged in 2015 when Ethereum, the second public blockchain, was issued by Vitalik Buterin as an option to Bitcoin. Smart contracts are contracts set up with the blockchain which operate automatically upon meeting specific conditions. This way, the need for a third-party intermediary to supervise transactions in real-time is eliminated. Smart contracts are an extension of the blockchain that can freely impose rules without the need for manual intervention (Nawari and Ravindran, 2019). They can also be treated as automatable conventional contracts since they have components that still may need human input and supervision (Li *et al.,* 2019).

With smart contracts, payments, submissions and project updates can be done automatically, which makes the entire process more efficient. All the data and information recorded (e.g. the number of working hours) and transactions (e.g. payments) are logged on the blockchain. This way, the whole process is transparent and traceable for all the collaborative parties. If there is an error (e.g. a specification in the smart contract with the concession of all the participants), a reverse transaction can be quickly done. The major benefit is that all these processes are transparent and tamper-proof for all the participants.

The integration of oracles is necessary for smart contract enabled processes. Oracles are collaborators that can be either external parties (e.g. on-site engineer) or sources of information (e.g. ID registering gate). Oracles are collaborators which establish the link between smart contracts and the process they control (Refer to Figure 2.5) (Penzez, 2018).

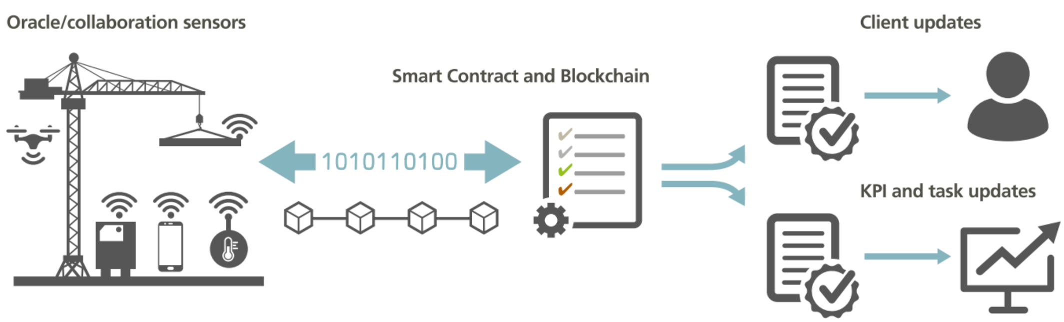


Figure 2.5 Example of the use of oracles on-site for smart contracts

Source: Penzez (2018)

2.3.2.5.1 Smart contracts and BIM

As per Winfield-Rock Report, the integration of blockchain and smart contracts can address some issues related to BIM implementation, including collaboration and trust. That is because of the opportunity of a real-time, hack-resistant and change-resistant record of data with reliable time entries boosts the integrity, trustworthiness, and transparency of the data (Li *et al.,* 2019). Smart contracts can also be set up to automatically give rewards or take back privileges depending on the completion of certain conditions, and be used as a permanent repository of all the changes made to the BIM model data, including other related information (Nawari and Ravindran, 2019).

2.3.2.5.2 Benefits of using smart contracts

The use of smart contracts offers multiple benefits to the built environment and the construction industry. A summary of these benefits comprehend:

- **Fast agreements**: Smart contracts are automated by computer code and liked to a universal blockchain. Therefore, digital tasks can be executed faster and more often. For instance, if a smart contract is implemented to pay a contractor, the payment can be made nearly instantly once the work is finished.
- **High accuracy:** Assuming that smart contracts are written correctly, tasks executed through them will be highly accurate because they completely follow a computer code, which discards practically any possible mistakes.
- **Trustless:** Since there are no intermediaries in smart contracts agreements, the need for trusts in any company or participant is eliminated (ARUP, 2017).
- **Lower costs**: Not depending on their party intermediaries is also beneficial in reducing or eliminating related costs (e.g. administration, project control, overheads). For instance, legal fees can be notably decreased if several scenarios or contingencies are written into the smart contract as a code. Since project procurement information is recorded in a way that can be traced, it allows

project evaluation and cost increase observations. Additionally, since repetitive activities can be automated, the cost of implementing smart contracts would represent only the creation of the contract itself (ARUP, 2017; Penzez, 2018).

- **Transparency**: The contracting process is transparent and easy to follow because every transaction, payment, business interaction and performance can be registered on the blockchain (Penzez, 2018).
- **Less risk:** The use of blockchain in the development of smart contracts makes them more secure tools than traditional contracts which need centralised counterparties (ARUP, 2017). Smart contracts can provide transparency and decrease the intricacy of the entire construction procurement process, which helps to reduce the risk of late payment and the number of disputes (Penzez, 2018).
- **Enhanced collaboration:** Contractual collaboration is automated and supported by smart contracts. The potential of smart contracts to reduce claims and disputes concerning the time spent solving them also enhances stakeholder relationships (Penzez, 2018).
- **Compliance:** Contractual standards can contribute to and be part of smart contracts. Including the project information on the blockchain as well, regulatory compliance can be simply determined (Penzez, 2018).

2.3.2.5.3 Challenges of using smart contracts

The main challenges of implementing smart contracts encompass storage, preservation of documentation, the trustworthiness of the data, interoperability, confidentiality and the difficulty of coding them, considering the potential durability needed.

Also, numerous aspects need to be solved for their implementation such as unexamined legal issues, the continuous necessity for transparent and express contract conditions, and mitigating procedures to diminish the risk that participants take on unexpected obligations and disputes. Further barriers to the dissemination of smart contracts involve lack of well-defined legislation on the imposition and administration of smart contracts; limited abilities to understand and convert legal text into machine-readable contracts; security concerns; and intricacy of contracts network (Li *et al.*, 2019).

Another critical challenge of smart contracts is to create a process as secure as blockchain is. If data registered in the smart contracts is corrupted, wrong decisions can be made. Since the rise of IoT is a reality, the use of interconnected sensors as a close data source for smart contracts is suggested to remove possible human errors (Penzez, 2018).

2.3.3 Internet of Things

IoT is a structure of interconnected smart devices that have the potential to transfer data over a network without the need of neither human-to-human nor human-to-computer communication (Li *et al.,* 2019). IoT objects can be animals, plants, people, devices, building elements, etc. An Internet Protocol (IP) address is located onto these objects so they can communicate with each other on the network. They are usually called smart objects (e.g. smart meter) (BIM Wiki, 2019d).

IoT is drastically changing the construction industry. IoT technology provides benefits to construction projects not only in the construction phase of but also for facilities management once projects are built and used. IoT has also enabled the development of "smart" or "digital buildings" (Urie, 2019). Some of the applications of IoT in the construction industry include:

- **Green buildings**: Green buildings are being designed with IoT technology to improve energy management. For instance, louvres can be set up to close or open automatically to let in natural light.
- **Smart prefabrication**: IoT can help in the coordination of prefabricated elements in large projects, which is usually a difficult task with traditional methods. Radio-frequency identification (RFID) sensors can be used to track prefabricated elements throughout the supply chain.
- **Construction management.** IoT can prevent delays and save money through predictive maintenance in construction equipment. For instance, sensors can be installed to monitor construction equipment. If something unusual is found, they can generate alerts so workers can act timely before the equipment fails projects (Levy, 2017). Construction equipment and tools can also be tracked, which

reduces the time of looking for lost or misplaced objects and avoids unnecessary investment on replacements.

IoT also allows just-in-time provision of supplies. If units of supply have been labelled with RFID tags, a system can count them on site. When the count is below a given number, the system can generate an alert to order more. This way, idle time is reduced, and the project can be finished on time. Moreover, costs are reduced because companies do not order more than what is needed (Urie, 2019).

- **Health and safety:** IoT technology (wearable devices) can also be used to monitor the health, attentiveness and working conditions of construction workers to avoid fatigue and diminish the risk of potential accidents.
- **Augmented reality:** For instance, AR can be incorporated into equipment visors and vehicle windshields to provide a virtual map of the site. Also, data gathered from IoT sensors can be displayed in real-time and superimposed onto the real-world to look at a task that needs to be executed (Urie, 2019).
- **BIM:** When a building is operating, data from IoT sensors can be extracted and embedded into the BIM model. This data can be used to obtain information about the buildings' operation (e.g. energy usage patterns, people movement within the building, etc.), which can subsequently be analysed to enhance future buildings projects (Levy, 2017).

Data collected from IoT sensors lay the foundations for the use of big data, artificial intelligence and machine learning. That contributes to the planning of future projects and allows builders to make better predictions about projects, from financial aspects to the resources needed for their development (PBC Today, 2019).

2.3.3.1 Challenges to implementing IoT

Challenges to implementing IoT include, and are not limited to:

- Slow adoption among construction workers, which can be attributed to the fragmented nature of the construction industry, where work is divided by contractors and subcontractors.
- The conditions of the site determine the use of IoT. For instance, smaller sites with a few workers do not necessarily need the implementation of sophisticated software or sensors since a foreman can effectively supervise them.
- IoT devices rely on good connectivity. When connectivity is lost, they cannot send data in real-time, which hinders their functions.
- IoT technology deals with large amounts of data; therefore, there is a risk that data may not be managed and processed appropriately.
- Despite their benefits in the operation of buildings, smart buildings can raise privacy concerns among users.
- There are also security issues around Building Management Systems (BMS) since they can be prone to hacker attacks trying to take control or handle systems by using malware.

- How smart a building is will affect its cost. A building with a few smart devices will cost less than a fully smart building (Urie, 2019).

2.3.4 Big data

According to IBM (2015), humans generate 2.5 quintillion bytes of data daily, and 90% of the data in the world has been produced in the last two years. This increase in high-volume data has been defined as big data (BIM Wiki, 2019b).

The construction industry is also taking part in this data revolution since it is managing relevant data generated from different disciplines during the lifecycle of an asset (Bilal *et al.*, 2016). In buildings, data can be produced by a vast amount of sources, which includes design and construction (through BIM); post-occupancy evaluation; utilities, building services, building management systems (BMS), meters; ICT systems and equipment, maintenance and replacement systems; operational cost monitoring; enterprise systems (e.g. purchasing systems, work schedules, etc.); and infrastructure and transport systems (BIM Wiki, 2019b).

Big data is spreading slowly within the construction industry, but its use can be propelled by emerging trends such as BIM, IoT, smart buildings, cloud computing, and augmented reality (Bilal *et al.,* 2016). An obstacle for the use of big data in the construction industry is that much of the data that has already been gathered is in silos which can be useful to conduct analytics on certain disciplines/departments but not for the whole project. Big data can bring solutions to the construction industry in aspects such as the development of large and complex buildings and sustainable design. The future of big data is promising if the current collaboration between the industry and technology development continues (Marr, 2016).

2.3.5 Digital Twin

Digital twins are a representation of a system that imitates its real-world performance (including its surroundings in some occasions). They are usually the product of a real-time updated collection of data, models, algorithms or analysis (NIC, 2017). They can be considered a natural evolution of BIM, which is currently used to represent the built environment digitally (BSI, 2018c). Digital twins facilitate enhanced use, operation, maintenance, planning and delivery of assets, services and systems (Bolton, Enzer and Schooling, 2018).

To be implemented successfully, a digital twin must depict its physical reality with the appropriate level of accuracy for its function. The degree of reality of the digital twin is based on three major aspects:

- Data: the quality of data on which the twin has been formed.
- Model: the reliability of the algorithms, the legitimacy of the expectations and the capability of the code at the core of the digital duplication.
- Visualisation: the quality of the presentation of the product (Bolton *et al.,* 2018).

One typical use of digital twins is modelling buildings systems. They utilise information and operational technology such as floor plans and construction data of the building, real-time sensor data from the building management system, data from different systems (lighting, fire, HVAC, etc.), data of the elements of the building as well as data from people that use it (e.g. building personnel, inhabitants, tenants, visitors, etc.).

Blockchain, IoT and artificial intelligence can contribute significantly to the development and use of digital twins. The data gathered for the creation of digital twins can come from different sources. An authentic digital twin needs to be a "system of systems" combination, which can include wireless sensor networks, embedded sensors, digitised building lifecycle data and systems and the convergence with other cloud services and data providers (Jonhson Controls, 2019). Digital twins can integrate IoT data services to be able to collect such type of data. This way, digital twins do not only represent the "as-built" state of an asset but can also become a "live" and information-rich control panel and reporting tool for facilities management (Penzez, 2018).

With blockchain, digital twins can have vital information to design operational strategies, preventive maintenance or decommissioning procedures. Blockchain also guarantees that all these data can be traceable. For example, if a specific part of a structure suddenly fails, the digital twin facilitates the identification of which elements have caused the incident, and who was responsible for its assembly and procurement. This approach diminishes the time and cost of possible insurance disputes and warranty claims, as well as the intrinsic incentive of the involved participants of the project. During Operation and Maintenance (O&M), blockchain also makes sure that the quality of the data IoT services is adequately checked and in compliance with the clients' requirements verified (Penzez, 2018).

As the data embedded into digital twins increase in volume and complexity, analytics and artificial intelligence are becoming necessary to connect and understand this data; thus decision-making processes can also be enhanced (BSI, 2018c).

2.3.5.1 Benefits of digital twins

Organisations involved in the design, build and maintenance of assets can perform trials in the digital twin prior doing anything in the real-life asset which can save costs and diminish the risk of things not working correctly in the real world. Furthermore, digital twins can forecast what happens next. For instance, analysis in the digital model can show when signalling equipment can probably stop working or when certain elements need to be maintained (BSI, 2018c).

Jonhson Controls (2019) further stated that before and during the construction stage, digital twins could detect and enhance systems communications and connections, installation clashes, cost and maintenance estimations, construction risks and selection of providers. After the construction stage, they can anticipate safety incidents, system defects, components replacement schedules and process integration impacts.

Other potential benefits of digital twins include:

- Enhanced decisions regarding the type, timing and scale of assets required. For instance, when a new power plant is needed.

- Improved decisions on when to substitute or maintain assets.
- Enhancing safety and reducing other risks. For instance, integrating digital twins with virtual reality to perform virtual walk-throughs of assets.
- Better productivity from design to maintenance phases, including higher efficiency of the workforce and decreased waste of building materials.
- Enhancement of services that are based on physical infrastructure such as transport and utilities (BSI, 2018c).

2.3.5.2 Challenges of digital twins

One of the main challenges of digital twins is how difficult their creation is. A complete digital twin would require the input of multiple individual assets and rich related data. Other important challenges comprehend:

- Interoperability issues, which includes data models and Artificial Programming Interfaces (APIs).
- Commercial and contractual models.
- General understanding of digital twins, supported by a universal language.
- Changing behaviours to drive innovative and digitally-enabled practices (BSI, 2018c).
- *Lack of standards*. Standards would assist organisations in making smart technology development investments of this type.
- *Cybersecurity*. Cyber hackers could access to private building information contained within the digital twin.

- *Excess of technology*. Digital twins are not constantly demanded and can make things more difficult needlessly.
- *Change management*. Digital twins are as good as the data embedded in them. Similar to BIM models, digital twins need to be kept up to date (Jonhson Controls, 2019).

2.3.5.3 National Digital Twin

An interesting initiative in the UK concerning the use of Digital Twins is the creation of a National Digital Twin (NDT), whose roadmap is presented in the National Infrastructure Commission's report "Data for the Public Good". The NDT is a digital model of the UK infrastructure which will have the capacity to oversee the infrastructure of the country in real-time and perform simulations of the effect of potential events (e.g. a new train line or a natural disaster). With this project, the UK will have the possibility to show global leadership in the field of digital twin technology.

The development of the NDT will be supported by big data and machine learning methods. It would join individual infrastructure models by collecting data on national infrastructure and the interdependencies between infrastructure systems, supporting the creation of a data-driven economy in the infrastructure sector (NIC, 2017). The NDT does not intend to be a massive digital model containing the whole built environment. Instead, it is predicted that it will involve the federation of digital twins brought together through strongly shared data (Bolton *et al.*, 2018).

2.3.6 Artificial Intelligence

Artificial Intelligence (AI) has been acknowledged as a key component of Industry 4.0 (Maskuriy *et al.*, 2019). AI is a category of computer science which refers to a machine's capacity to execute some tasks smartly, thinking and functioning the same way as natural intelligence. AI encompasses technologies that can execute difficult activities that were conventionally seen out of the computer's range such as speech recognition, visual perception, reasoning, natural language processing, learning from data and solving different types of optimisation problems (NIC, 2017; BIM Wiki, 2019a). The adoption of AI solutions is significantly low in the construction industry, compared to leading sectors such as Financial Services, High tech and communications, and Transportation and Logistics. Nonetheless, there is a small group of start-ups that are gaining competitive advantage and attention thanks to their AI-focused approaches (Blanco *et al.*, 2017).

2.3.6.1 Applications of AI in the construction industry

AI includes a wide range of technologies such as machine learning, robotics and natural language processing. Important applications of AI in the construction industry encompass:

- **Optimisation of project planning:** An AI technology named *reinforcement learning*, in which algorithms learn based on trial and error could be used in project planning and scheduling. Innumerable combinations and options from projects of the same type can be assessed to select better routes and correct themselves along the way.

- **Prediction of constructability issues:** Predictive AI solutions can be used to predict projects risks, constructability, and structural stability of several technical solutions, which can ease the decision-making process. These solutions can also be used to test construction materials.
- **Optimisation for materials and inventory management:** AI can reduce manufacturing spare time and oversupply, and have a more accurate prediction of shipments which subsequently would significantly reduce costs, logistical issues, and inconsistencies in construction projects.
- **Use of robotics:** Robots can be used for prefabrication techniques and maintenance operations in the construction industry (Blanco *et al.*, 2018). There is also construction machinery that can execute repetitive tasks better than humans such as bricklaying, demolition, welding, pouring concrete. This discharge humans for this type of work and reduces the completion time of a project. Furthermore, there are off-site factories operated by robots that assemble building components, which need to be later assembled on-site by human workforce (Rao, 2019).
- **Image recognition for risk and safety management:** Image recognition can be incorporated into drone imagery, and 3D generated models to evaluate issues related to quality control; for instance, early identification of dangerous

events (e.g. failure of a structure). These methods could allow the comparison of developing and final products against their original concept, or train an un-safe behaviours indicator algorithm to detect safety risks on-site from a massive collection of drone images (Blanco *et al.*, 2018). Project managers can monitor site work in real-time through technologies like facial recognition and onsite cameras (Rao, 2019).

- **Better designs through generative design:** Machine learning can be used in the form of generative design for the identification and reduction of clashes between models created by different teams; thus, avoiding rework (Rao, 2019). Machine learning is a subset of AI which enables computers to execute certain tasks intelligently by learning from data, examples and experience (NIC, 2017). Generative design is a method where computation is used to enhance the designer's capacity to define, discover and select design options through automatisation. A software algorithm can explore various potential solutions and identify the best one. This way, designers can develop better and more functional final designs (Autodesk, 2018).

- **Risk management:** Nowadays, general contractors can use AI and machine learning solutions to track and prioritise risk on the project site. Subcontractors can be rated based on risk points. Thus, construction managers can work carefully with the identified high-risk teams to reduce risks opportunities (Rao, 2019).

- **Solution to labour shortages:** AI and machine learning are being used by construction companies to create better strategies for distribution of workforce and machinery across projects. For instance, robots can regularly assess job progress and the location of workers and machinery, which allows project managers to detect whether they need or not extra personnel and machinery.
- **Big data:** AI can benefit from the use of big data. Project sites are becoming important data sources for AI thanks to the use of different methods for data generation nowadays: drone videos, security sensors, images from mobile devices, BIM, etc. That opens numerous opportunities for the implementation of AI and machine learning in the construction industry.
- **Post-construction:** Supported by BIM, which allows the storage of information about the building, AI can be used long after a project is finished to track developing problems and provide solutions to avoid problems in the future (Rao, 2019).

2.3.6.2 Challenges

Despite its multiple benefits, AI is not without challenges. These challenges include and are not limited to:

- Just a few companies or owners have the necessary capabilities (considering processes, tools and personnel) to implement AI technologies.
- Since any AI algorithm is created learning from the past, large amounts of data are necessary for AI to reach its potential. Therefore, companies will need a

substantial amount of data (e.g. from projects) to train an AI algorithm. That implies that large companies will be in more advantage than SMEs, especially in the short term (Blanco *et al.*, 2018).

- It has been forecasted that AI will cause significant job losses. Furthermore, some people have the fear that AI would replace human workers. However, this is unlikely to happen. AI will instead change business models within the construction industry, decrease expensive mistakes, diminish worksite accidents, and optimise building operations (Rao, 2019).
- AI will reduce or eliminate most of the easy tasks performed in the industry, which can be counter-productive if AI completely substitutes most of the tasks in which professionals learn how the industry works.
- Since computers are coded to substitute human thinking, ethical considerations in construction professions would need to be re-evaluated (Chapman, 2016).

2.3.7 Need for Open standards

To make digital technologies a common practice in the construction industry is necessary to implement open and accessible standards to assist all the stakeholders within the supply chain (Baldwin, 2019). Open standards propel innovation. They promote the development of new technologies, optimise processes and makes things easier to use. A great example of open standards is the internet. Without open standards, protocols and file formats, computers and networks would not interact with each other.

Alike the internet, the construction industry usually depends on and requires the use of open standards, primarily due to the complexity of modern construction projects. The next breakthrough in terms of productivity in the construction industry is automation. In the process of transitioning from human-readable documents to machine-readable data, it will be required the use of open standards to facilitate the selections of tools to be used (Granholm, 2019).

Interoperability is key in fulling realising the benefits of implementing IoT devices and systems. Interoperability in this field can be achieved by implementing open standards and systems or platforms that allow different IoT systems to interact with each other (Manyika *et al.*, 2015). Open standards are highly needed for the integration of IoT in the construction industry because of the abundance of protocols and information exchange standards used in both domains (Dave *et al.*, 2018). If IoT devices can interact over non-proprietary open standards as it is estimated, blockchain technologies would allow value to be transferred over a network. This way, blockchain can increase the opportunity of a value-transfer system in which people and machines can use a sensor's data stream (ARUP, 2019).

Digital twins also demand an open information environment to coordinate and access data in a more effective way. Currently, most projects start with some sort of BIM model, which should include important asset information that can be beneficial for a digital twin if it is used appropriately. The models created for a digital twin need to be aligned so they can be used universally. That is the only way to develop a workflow to link digital data; if not, data can become obscure and unreachable. Nowadays, buildingSMART is facilitating digital ways of working and is currently looking into the development of an open standard for a digital twin (buildingSMART, 2019).

2.4 Summary

This chapter has addressed the first objective of this research which is *"To critically analyse the concept of Building Information Modelling (BIM) and emerging technologies related to its implementation".* A brief history of BIM implementation in the construction industry was provided along with the definition of BIM used for this study and a brief explanation of how BIM is used in the construction industry. Furthermore, other important topics surrounding the concept of BIM were presented. BIM dimensions were explored considering the following classification: 3D, 4D, 5D, and 6D. The concept of BIM maturity was explained along with two important models used to describe BIM maturity: the Bew-Richards BIM maturity model and the BIM maturity stages by Bilal Succar. The concept of OpenBIM was introduced as it is key in enabling collaboration in the construction industry through the use of open standards and formats. Then, the literature review focused on the emerging concepts, processes and technologies related to BIM implementation. This discussion started with the introduction of the concept of Industry 4.0, where BIM plays an important role in the context of the construction industry. Other topics include blockchain, smart contracts, Internet of Things (IoT), big data, digital twin and artificial intelligence, from which their current and promising applications in the construction industry and BIM were highlighted. Lastly, it was emphasised the need for open standards for the implementation of BIM and the studied concepts, processes, and technologies.

The next chapter (i.e. Chapter 3) presents a literature review on BIM implementation around the world, highlighting the initiatives and key players that have introduced and driven the implementation of BIM in the studied countries.

CHAPTER 3: AN OVERVIEW OF THE IMPLEMENTATION OF BIM WORLDWIDE

3.1 Introduction

The implementation of BIM is increasing vigorously, propelled by prominent private and government owners who want to systematise the benefits it offers: quicker and more reliable project delivery and more guaranteed quality and cost (McGraw-Hill Construction, 2014a). Nowadays, powerful economies are contemplating a national BIM mandate or are already implementing one because they consider that the implementation of BIM is an essential step in reducing lifecycle building costs (McGraw-Hill Construction, 2014b).

This chapter corresponds to the second objective of this study, which is "*To investigate BIM global implementation initiatives to identify the critical enabling factors for country-wide BIM implementation*". To attain this objective, a literature review on BIM implementation around the world was undertaken. The initiatives and key players of BIM implementation were studied to identify the critical enabling factors for country-wide BIM implementation.

Since there is a wide range of countries that could be studied in this review, criteria were established to select a sample of countries. First, there were selected early BIM adopters, meaning they have been pioneers in the implementation worldwide and, therefore, are mature in the implementation of BIM. The early BIM adopter countries considered were: United States of America; Finland, Denmark and Norway from the

Scandinavian region; the United Kingdom; and Singapore. Secondly, there were selected late BIM adopter countries, meaning that they have recently embarked into the BIM journey compared to the early BIM adopters. These countries, in particular, were studied to relate their BIM implementation journey to the situation in the D.R., which can also be considered as a late BIM adopter. The late BIM adopter countries considered for this study were China and Hong Kong from Asia; and Brazil, Chile and Mexico from Latin America. China and Hong Kong present excellent examples of BIM initiatives, regardless of their late involvement and, yet, have low levels of BIM implementation. On the other hand, Latin American countries have more recent implementation strategies than the aforementioned Asian countries. The inclusion of Latin American countries in the study was necessary, in particular, due to the geographical context of the Dominican Republic.

Lastly, since the focus of this study is the Dominican Republic, the chapter also includes a literature review on the implementation of BIM in the country.

3.2 Early BIM adopter countries

3.2.1 United States of America

The United States of America is one of the earliest BIM adopters in the world and is currently the most significant producer and purchaser of BIM products. The main difference between the USA and other countries may be that there is not a mandate to be applied nationwide (McGraw-Hill Construction, 2014b). Instead, different players of the public sector contribute to BIM implementation, from national entities to public universities (Cheng and Lu, 2015). There are numerous players and initiatives towards BIM implementation in the United States. Following, the most relevant players and BIM initiatives in this country will be discussed.

3.2.1.1 BIM initiatives from the public sector

3.2.1.1.1 Government agencies

Two public sector agencies, the GSA (General Services Administration) and USACE (United States Army Corps of Engineers), have developed policies requiring the use of BIM for their projects (McGraw-Hill Construction, 2014b). The GSA, the organism responsible for the construction and operation of all federal facilities in the country, initiated the implementation of BIM in public projects (Smith, 2014c). In 2003, the GSA PBS OCA (Public Building Services) (Office of the Chief Architect) introduced the National 3D-4D-BIM program, with the following purposes:

- Set out a policy to gradually implement 3D, 4D, and BIM in all major projects.
- Lead 3D-4D BIM pilot applications and incentives for current and upcoming capital projects.
- Provide expert assistance and evaluation for on-going capital projects to integrate 3D, 4D and BIM technologies.
- Evaluate industry readiness and technology maturity.
- Associate with BIM software providers, professional organisations, open standard organisations, and academic and research entities (Wong *et al.*, 2011a; Cheng and Lu, 2015).

The GSA adopted a series of initiatives to meet the aim of its BIM programme: Pilot projects, Laser scanning of buildings, Mandate IFC-based BIM for building analysis and design, Avatar technology for people simulation, Demonstration of energy-efficient design, Communication of BIM's adoption, Partnership with software developers, and International cooperation with real estate associates (Norway's Directorate of Public Construction and Property, Finland's Senate Properties, and Danish Enterprise and Construction Authority) (Wong *et al.*, 2011a).

In 2006, the U.S. Army Corps of Engineers (USACE) launched "Building Information Modelling: A Road Map for Implementation to Support Military Construction (MILCON) Transformation and Civil Works Projects within the U.S. Army Corps of Engineers", with a staged plan of six long-term goals to be attained by 2020. The objective of this roadmap was the use of BIM to enhance the planning, design and construction processes of the USACE and make this institution a BIM leader (Brucker *et al.*, 2006). In 2012, this roadmap was updated with the release of the *Roadmap for Life-Cycle BIM* to be implemented in military construction and civil works (Cheng and Lu, 2015).

3.2.1.1.2 States

The States of Wisconsin, Ohio and Tennessee have required the use of BIM and produced standards accordingly to guide the implementation of BIM in "state projects" (Cheng and Lu, 2015) (Refer to Table 3.1).

Table 3.1 BIM standards and guidelines developed in Wisconsin, Ohio and Tennesse

Adapted from Cheng and Lu (2015)

State	BIM standards/guidelines	Year
Wisconsin	BIM Guidelines and Standards for Architects and Engineers	2009
Ohio	State of Ohio BIM Protocol	2011
Tennessee	BIM Requirements V1.0	2013

3.2.1.1.3 Other public institutions

The National Institute of Standards and Technology (NIST) is a physical science laboratory that belongs to the U.S. Department of Commerce which aims to promote industrial competitiveness in the USA (NIST, 2015). Regarding BIM, the NIST has carried out research on BIM and interoperability (Wong *et al.,* 2010) and released BIM guidelines (Cheng and Lu, 2015).

CAD/BIM Technology Center, a research centre for the USACE, offers technical and professional services for BIM implementation and promotes interoperability between BIM and other geospatial applications (Wong *et al.*, 2010). Its activities include the creation of standards, promotion of system integration and the provision of support for training, installation, operations and maintenance of CAD and BIM systems (CAD BIM Technology Center, 2016).

3.2.1.2 BIM initiatives from the construction industry

3.2.1.2.1 Professional organisations

The American Institute of Architects (AIA) has been involved with BIM through different actions and roles: the creation of interoperability standards, coordination of activities in the construction and real estate industry, elaboration of articles and white papers, presentations on integrated practice, and support for the implementation of computer technology in Architecture (Wong *et al.*, 2010). A significant contribution from the AIA not only to BIM adopters in the USA but to the broader community has been the development of the LOD (Levels of Development) framework established in 2008 in the AIA E202 document (McGraw Hill, 2012).

The Association of General Contractors of America (AGC) has created BIM standards and guidelines (e.g. The Contractor's Guide to BIM Edition 1, BIM guide, etc.) (Cheng and Lu, 2015). The AGC established the BIMForum, a task force for BIM where members work together virtually through an online forum (Wong *et al.*, 2010). BIMForum investigates technological innovations through BIM and new means of collaboration to improve the working patterns in the industry by offering education and developing best practices for these innovations. BIMForum is a US Chapter of buildingSMART International; therefore, they also promote and support the adoption of openBIM standards across the industry (BIMForum, 2017).

3.2.1.2.2 Non-profit organisations

The National Institute of Building Sciences (NIBS) is a non-profit and non-governmental organisation that gathers representatives from the government and the industry to identify and bring solutions to problems that hinder the construction of safe and affordable buildings across the country (NIBS, 2016). The NIBS is responsible for the development National BIM Standard (NBIMS), buildingSMART Alliance, manages the Journal of Building Information Modeling and performs as a link between the government and the private sector (Wong *et al.*, 2010; NIBS, 2016). The NIBS set up the NBIMS-USTMproject committee to create national BIM standards and contemplate opportunities of integrating BIM into college curricula. Additionally, in 2014 the NIBS introduced its first training courses named "The Introduction to COBie" in the Building Sciences Only Academy of the institution (Cheng and Lu, 2015).

3.2.1.3 BIM Education and training

Interestingly, public education institutions in the United States have taken part in the development of BIM standards since 2009 (Cheng and Lu, 2015). Some of them have developed standards to guide the implementation of BIM in general while others have done it as part of their BIM requirements for projects in their campuses (Refer to Table 3.2).

By 2019, there were 68 public and 39 private universities delivering formal Architecture and Engineering Programmes in the USA. Most of them are accredited to provide undergraduate programs in the three disciplines of the AEC industry and all of which give some BIM courses as part of their curricula. The most important institutions include Brigham Young University, Purdue University, Pennsylvania State University, Georgia Southern University, Georgia Tech University, University of Oklahoma, and the University of California – Irvine.

Furthermore, the AGC, along with leading BIM users, technology companies and educators, created a BIM Education Program composed of four units. Once participants complete the four units, they become qualified to take an exam to get the Certificate of Management-Building Information Modelling (CM-BIM) (Rooney, 2019).

Table 3.2 Universities of the USA involved with BIM through BIM mandates and the development of standards

Source: Cheng and Lu (2015) and Rooney (2019)

University	Non-exhaustive list of standards
Standards and guidelines for general use	
Penn State University (PSU)	Development of several guides since 2009 (10 thus far) aiming to offer BIM guidance in different aspects, for example, *BIM Project Execution Planning Guide*, *BIM Planning Guide for Facility Owners*, *The Uses of BIM* and *Using Models in Construction: A planning Guide* (Cheng and Lu, 2015; PSU, 2017)
Standards and guidelines to be used in their projects	
Los Angeles Community College District (LACCD)	Including LACCD Building Information Modeling Standards for Design-Bid-Build Projects (LACCD BIMS) Interim Version 2.0; LACCD Building Information Modeling Standards (LACCD BIMS) Version 4.1 Design-Build (Cheng and Lu, 2015; BuildLACCD, 2017)
University of Florida	BIM Execution Plan
University of Connecticut	CAD Standards Guideline
Indiana University	IU BIM Guidelines and Standards
University at Albany	AECM BIM Guidelines 2012 for electronic submission of BIM projects (Cheng and Lu, 2015)

3.2.1.4 Levels of BIM adoption

The levels of BIM adoption in the U.S.A. have not been regularly assessed. The latest statistics registered presented a significant increase in the adoption from 2009 to 2012 across the country (McGraw Hill, 2012) (Refer to Figure 3.1).

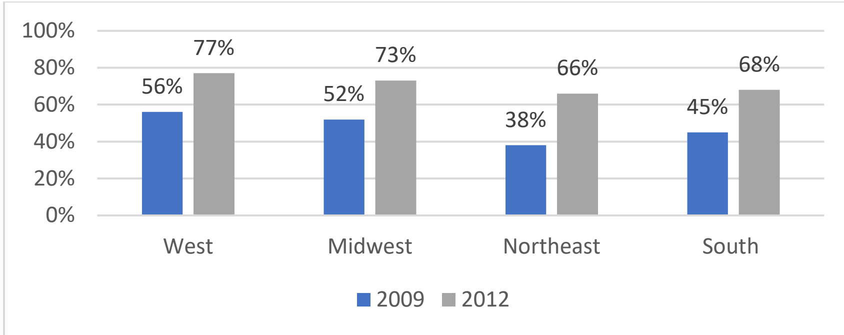


Figure 3.1 Levels of BIM adoption in the USA by region

Source: McGraw Hill (2012)

3.2.2 Scandinavia: Finland, Denmark and Norway

Scandinavian countries are known for being technologically advanced with large public sectors and a very educated population. Also, the state plays a vital role in driving the implementation of new technology (Jensen and Jóhannesson, 2013). The Scandinavian region is one of the first adopters and current global leaders of BIM (Wong *et al.*, 2010; Smith, 2014c). It can also be argued that the region is the pioneer of BIM interoperability as they have created the technology and vendor-neutral standard Industry Foundation Classes (IFCs), which is one of the most popular collaboration formats used in BIM (Wortmann, 2016).

The implementation of BIM in the Scandinavian region has been led mostly by Norway, whose Public mandate was established in 2010; and Finland and Denmark, with Public mandates set in 2007 (Wong *et al.*, 2010; McGraw-Hill Construction, 2014b; Cheng and Lu, 2015). In particular, Finland and Norway are two of the most developed BIM countries in the world (McGraw-Hill Construction, 2014b). Sweden is a late adopter in the region, with a public mandate having set in 2013 by the Swedish Transportation

Administration requiring the implementation of BIM from June 2015 (Cheng and Lu, 2015; Davies *et al.*, 2015). Therefore, it has not been considered for the analysis of early BIM adopter countries within this region for this specific study.

The mandates from Finland and Norway are more rigid and focused on the delivery of IFC data at different stages of the project's lifecycle. On the other hand, the mandate in Denmark has a performance-based approach, which establishes performance goals and guidelines to develop BIM projects, giving liberty to the industry of selecting how to do the delivery of data. The mandate in the UK would follow a similar approach later.

Scandinavia has supported its long-term objectives with actions that excel apart from their public mandates, which include:

- Destining resources for education, training and diffusion of case studies.
- Establishing guidelines, instructions, and process support pertinent to the implementation of BIM.
- Enhancing the delivery of BIM education at the university level (McGraw-Hill Construction, 2014b).

3.2.2.1 Finland

3.2.2.1.1 BIM initiatives from the public sector

3.2.2.1.1.1 Government entities

Since the 1970s, the Finnish Government has made considerable investments in IT research in the construction industry (Smith, 2014c). The Finnish public sector has been a critical driver for BIM adoption in the country (Wong *et al.*, 2010; Smith, 2014c, Cheng and Lu, 2015).

Senate properties, the largest government entity under the Finnish Ministry of Finance that supervises the country's property assets, has led the implementation of BIM in Finland (Smith, 2014c, Cheng and Lu, 2015). The entity has executed several pilot projects using BIM since 2001 to promote the use of product models (Gajendran, Brewer and Le Goff, 2012). Based on the positive results, the use of IFC/BIM for its projects was mandated in 2007, which implied that all the software packages had to be checked against the current version of IFC. Also, it created modelling guidelines for project participants to know the modelling data requirements at each design phase (Wong *et al.*, 2010; Cheng and Lu, 2015). In 2012, Senate Properties developed its BIM Requirements for Architectural Design into the Finnish National BIM Guidelines (COBIM) producing the Common BIM Requirements 2012 v1.0, along with various construction companies, consulting companies and large cities (Cheng and Lu, 2015). This entity has also cooperated with the GSA to support open standards and BIM software and systems (Wong *et al.*, 2010).

3.2.2.1.2 BIM initiatives from the construction industry

3.2.2.1.2.1 Professional organisations

The Association of Finnish Contractors has also driven the implementation of BIM in the country (Travaglini, Radujković and Mancini, 2014). They have been actively promoting

BIM along with Senate Properties, and have collaborated with the GSA in the USA to establish openBIM standards (Wong *et al.*, 2010).

3.2.2.1.2.2 Research organisations

Additionally, research organisations have been highly involved in BIM research and other related areas (Wong *et al.*, 2010; Heikkila *et al.*, 2016) (Refer to Table 3.3).

Table 3.3 Public research organisations in Finland and their BIM initiatives

Source: Wong *et al.* (2010); VTT (2015); Tekes (2017)

Research organisation	BIM initiative
Tekes – funded by the public sector	• Research projects (Tekes, 2017)
VTT – under the mandate of the Ministry of Employment and the Economy	• BIM Research (Wong *et al.*, 2010) • Development of new technologies by advanced modelling, visualisation and gamification • BIM-based applications, service concepts and interfaces. • BIM implementation support for organisations: through vision and strategic roadmap work; creation of BIM guidelines, collaborative processes and new ways of working • Standardised methods for data exchange and interoperable information management (VTT, 2015)

3.2.2.1.2.3 Collaborative BIM Forum

BuildingSMART Finland is a collaboration forum established by Finnish Property Owners, A/E consultants, construction companies and software vendors. The objective of the forum is to diffuse information regarding BIM and support its member; thus, they can adopt BIM-based practices. The forum also seeks to encourage interaction between software vendors and end-users and arranges BIM-related seminars and events. They also offer a link to international BIM development. BuildingSmart Finland has also created BIM guidelines and manuals (Heikkila *et al.*, 2016).

3.2.2.1.2.4 Construction organisations

Similar to Senate Properties, the building contractor Skanska has been a key BIM implementation motivator (Heikkila *et al.*, 2016). They have implemented BIM and carried out research and development in BIM (Wong *et al.*, 2010).

3.2.2.1.3 BIM Education and training

There are several BIM programmes in higher education institutions. BIM is taught at any university that has the career of Civil Engineering and related areas (e.g. University of Oulu, Tampere, University of Technology, Aalto University) as well as at universities of Applied Science (e.g. Metropolia University). Moreover, BIM is also taught at the secondary level in several organisations, particularly infraBIM and related 3-D machine control. BuildingSMART Finland Education is responsible for supporting BIM education in the country (Travaglini *et al.*, 2014; Heikkila *et al.*, 2016). Several universities in Finland have conducted research and Research and Development (R&D): University of Oulu, Aalto University, Helsinki University of Technology and Tampere University of Technology (Wong *et al.*, 2010; Heikkila *et al.* 2016).

3.2.2.1.4 Levels of BIM adoption

The latest official survey of BIM in Finland was conducted in 2013 by NBS and the Building Information Foundation RTS with the participation of 400 professionals of different areas of the construction sector. The results showed high levels of BIM awareness, with 87% of the participants, and high levels of BIM implementation with 65% using BIM (Refer to Figure 3.2) (NBS, 2013).

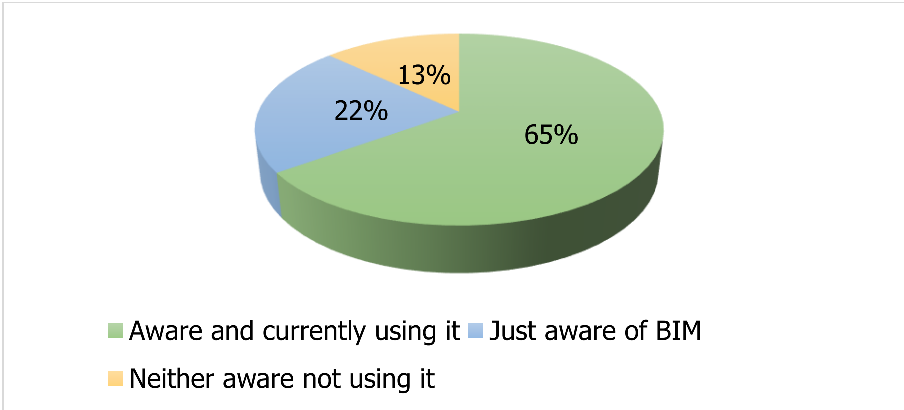


Figure 3.2 Levels of BIM awareness and implementation in Finland

Source: NBS (2013)

Nowadays, BIM is highly used in Finland, including infrastructure projects. Medium or small enterprises do not fully implement BIM; however, most large companies have implemented and benefitted from BIM (Heikkila *et al.*, 2016). According to Rooney (2019), large organisations such as Skanska, YIT and NCC implement BIM in 100% of their production.

3.2.2.2 Norway

The first initiative leading to the implementation of BIM in Norway took place in 2000 through the collaboration of digital e-submissions between two organisations: the Norwegian Building Authority and the Map Authority of Norway. After that, the Norwegian Building Authority determined that the use of BIM was necessary to provide drawing information on projects. Notably, they recognised the importance of using the Industry Foundation Classes (IFC) open standards for information exchange. By 2005, an extension of IFC was available to assist the interoperability between the map information and building information (McGraw-Hill Construction, 2014b).

3.2.2.2.1 BIM initiatives from the Central government

In 2010, the Norwegian government expressed their commitment to BIM adoption, and various public sector entities started BIM programmes to follow the government. For instance, the Norwegian Defense Estates Agency started developing BIM pilot projects after the government's announcement. Statsbygg, a public sector administration company and the Norwegian government's principal advisor mandated IFC-compatible BIM for all new projects by 2010 (Cheng and Lu, 2015). The mandate was established aiming to decrease faults and omissions, enhance communication and coordination, gain efficiencies, increment energy efficiency, and enhance the built environment practices through cutting edge research, technologies and processes (McGraw-Hill Construction, 2014b). To promote the use of BIM, Statsbygg has carried out R&D projects with a major focus on BIM for efficient building, location-based simulation, indoor navigations and energy calculations (McGraw-Hill Construction, 2014a; Cheng and Lu, 2015). Also, Statsbygg has released BIM manuals starting in 2008 with the BIM Manual v1.0 (Cheng and Lu, 2015).

3.2.2.2.2 BIM initiatives from the construction industry

3.2.2.2.2.1 Professional Associations

The non-profit association, Norwegian Home Builder's Association, initiated a project to create a BIM-manual guideline called boligBIM (Cheng and Lu, 2015). They have also motivated the adoption of BIM and IFC in the industry. Furthermore, the Norwegian IAI Forum has worked in the definition of the requirements for information exchange in compliance with the Information Delivery Manual (IDM), which assists the information exchange requirements for business processes in the construction industry (Wong *et al.*, 2010).

3.2.2.2.2.2 Research Organisations

SINTEF, a leading research organisation, has contributed to various internal and cross-department projects as part of the BuildingSMART initiative. They have also researched BIM and created BIM guidelines (Wong *et al.*, 2010).

3.2.2.2.2.3 Construction organisations

In the private sector, specifically in the technology field, Selvaag-Bluethink has gotten involved in the development of IFC-based BIM (Wong *et al.*, 2010).

3.2.2.2.3 BIM Education and training

Regarding education, various students' projects have been developed at the Norwegian University of Science and Technology (NTNU) (Wong *et al.*, 2010). Currently, there is not a central government specification for BIM education in high education institutions. There are at least seven faculties that deliver openBIM courses and several colleges with special BIM studies. A few committed educators are encouraging openBIM education in colleges and universities.

Moreover, buildingSMART Norway is quite involved in BIM Education in the country. They started a programme in 2014 that concentrates on quality assurance of the content and output of courses. They have also developed three teaching plans (Basic, AEC and Client) which set up the minimum requirement for BIM training. These plans have already been used by private companies to develop their courses (Rooney, 2019).

3.2.2.3 Denmark

3.2.2.3.1 BIM initiatives from the Central government

The implementation of BIM in Denmark started due to the increased use of information and communication technology (ICT) aiming to develop better quality buildings and increase productivity in the industry. In 2002, the Danish government introduced a competitiveness package named "Will to growth". One of the purposes of this package was to enhance the productivity and competitiveness in the Danish construction industry through better use of ICT, from which the initiative *Digital Construction* was created (Jensen and Jóhannesson, 2013). This project was launched in 2007 to establish ICT requirements, including the use of BIM for governmental projects.

3.2.2.3.2 BIM initiatives from the public sector

Since the introduction of Digital Construction in 2007, several state clients (i.e. Palaces & Properties Agency, the Defense Construction Service and the Danish Property Agency) have developed BIM pilot projects and adopted the requirements established in the Digital Construction (Cheng and Lu, 2015). Gentofte Municipality and KLP Ejendomme are other government agencies which have implemented these requirements (Wong *et al.*, 2010).

In terms of guidelines, the National Agency for Enterprise and Construction (Erhvervs – og Byggestyrelsen), authorised by the Digital Construction Programme, launched four guidelines in 2007 for 3D CAD/BIM applications, which are available in English (Cheng and Lu, 2015).

3.2.2.3.3 BIM initiatives from the construction industry

3.2.2.3.3.1 Construction centres

The Construction Information Centre Molio (former Bips) has promoted BIM since 2003. Denmark buildingSMART has been part of this organisation since 2009. To support BIM adoption, the former bips released several standards (McAuley, Hore and West, 2017). During the period 2011-2015, they sponsored the project *cuneco*, a centre for productivity in construction. Cuneco has contributed to the creation of useful tools, especially the Cuneco Classification System (CCS) for BIM. CCS aims to use this system not only in Denmark but also in the European Union region, and potentially worldwide (Smith, 2014; NBS, 2016).

3.2.2.3.3.2 Construction organisations

The company Rambøll, in collaboration with MainManager, has developed a web-based system for the operation and maintenance of buildings in compliance with IFC named Rambyg (Wong *et al.*, 2010; MainManager, 2013).

3.2.2.3.4 BIM Education and training

In terms of education institutions, Aalborg University, Aarhus School of Architecture and Technical University of Denmark have worked in research and development programmes focused mainly on interoperability (Wong *et al.*, 2010). Following the mandate, the Technical University of Denmark delivers openBIM lectures in its BIM and

BIM-related courses in Undergraduate, Master and PhD level in the areas of Civil Engineering and Building Design (Karlshøj and Vestergaard, 2016). BIM is also taught at Undergraduate level in Architectural Technology and Construction Management degree of the Copenhagen School of Design and Technology (BIM Ireland, 2018).

3.2.3 United Kingdom

3.2.3.1 BIM initiatives from Central government

The United Kingdom has a remarkable BIM goal and is one of the most advanced countries in terms of BIM adoption (Cheng and Lu, 2015). In 2011, the Cabinet Office announced through the Government Construction Strategy that: *"Government will require fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016"* (Cabinet Office, 2011). In more detail, it was established that by 2016 all government projects had to implement BIM Level 2, regardless of projects size. Also, between 2016 and 2025 is projected that the UK Government and the industry will adopt BIM level 3 (Refer to Chapter 2, Section 2.2.2.1) (HM Government, 2013). The UK government mandate was formulated to reduce construction costs and the projects delivery time; allow the UK design and construction industry to be more competitive worldwide, and meet the carbon emission reduction targets for buildings (McGraw-Hill Construction, 2014b).

The BIM strategy in the country was first led by the BIM Task Group (HM Government, 2013). The BIM Task Group was an industry association, supported by the Department for Business Innovation & Skills and the Construction Industry Council. The BIM Task

Group connected experts from the government, industry, institutes and Academia to reinforce the BIM competence in the public sector and offer to the industry the necessary information to meet the government's BIM mandate (BIM Wiki, 2015).

Later in 2016, the Digital Built Britain (DBB) programme was launched, which constitutes the next phase of the BIM Task Group (HM Government, 2016). Digital Built Britain is based on the accomplishment of the BIM level 2 programme. It is aiming to support the next steps towards BIM level 3 to facilitate broader digitisation in construction and operation management (HM Government, 2017). In 2017, the Government announced the launch of the Centre for Digital Built Britain which is a partnership between the Department of Business, Energy and Industrial Strategy and the University of Cambridge. The Centre is keeping on the work of the Digital Built Britain Programme and the BIM Task Group. It supports the continuous transformation of the built environment through the use of digital technologies (Walters, 2017).

3.2.3.2 BIM initiatives from the construction industry

Government support has enabled the development of a network and groups of communities to drive BIM adoption including professional institutions: CIOB (Chartered Institute of Building, ICE (Institution of Civil Engineers), RIBA (Royal Institute of British Architects), RICS (Royal Institution of Chartered Surveyors), I.Struct.E (Institute of Structural Engineers), CIBSE (Chartered Institution of Building Services Engineers). Also, research and assistance organisations and networks have supported the implementation: NBS (National Building Specification), BRE (Building Research

Establishment), CIC (Construction Industry Council), CPIC (Construction Project Information Committee), CIRIA (Construction Industry Research and Information Association), and Regional BIM Hubs) (Davies *et al.*, 2015). For instance, the Construction Industry Council (CIC) prepared the Building Information Modelling (BIM) Protocol "CIC/BIM Pro" and has co-created some BIM guidelines along with the Centre for Digital Built Britain to assist BIM level 2 (Cheng and Lu, 2015). The British Standards Institution (BSI), a non-profit business standards entity, has also published BIM standards to manage the BIM level 2 process in the UK; for instance, the UK 1192 series. The AEC-UK is another non-profit institution involved not only in the development of BIM standards but also in the elaboration of BIM protocols for different software platforms (Cheng and Lu, 2015). The NBS has launched essential tools to drive the implementation such as the NBS Toolkit (Willis, 2015) and the NBS National BIM Library (Al-Saudi, 2014).

Another important organisation is the UK BIM Alliance, which is a cross-industry alliance created in October 2016 to lead BIM level 2 as well as the digital transformation of the construction industry. Its emphasis is the implementation of BIM Level 2 until 2020, which will set the fundamental aspects of BIM level 3 and digital transformation in the upcoming years (Bew, 2017).

3.2.3.3 BIM Education and training

The former BIM Task Group set opportunities to deliver resources, education, and training to the government and the industry (McGraw-Hill Construction, 2014b). In 2011 they established the BIM Academic Forum (BAF), a group of representatives from several UK universities that seeks to support the educational aspects of BIM. This group focused mainly on the creation of a BIM academic framework (Underwood *et al.*, 2013). The BAF published first a preliminary BIM Learning Outcomes Framework (LOF) to guide Academia, organisations, training providers and private educators in elaborating and delivering training programs to professionals in the industry (BIM Task Group, 2012). Later, in 2015, they developed a new version of the LOF in conjunction with the former BIM Task Group. This version contains the BIM level 2 support documents and covers academic and industry feedback on its implementation, presentation format, organisation and content (Underwood *et al.*, 2015). The LOF does not give training or programs content. It presents the topics that should be taken into consideration for a standard BIM level 2 execution (BIM Level 2, 2016).

3.2.3.4 Levels of BIM adoption

Since 2011, the NBS (National Building Specification) conducts annual BIM surveys in which allows to gauge the implementation of BIM in the country with up-to-date information and make comparisons with previous years. The most recent survey was conducted in 2019 and illustrated the adoption of BIM during the last nine years (NBS, 2019).

As presented in Figure 3.3, the adoption of BIM has grown gradually with 13% of the industry being aware and using BIM in 2011 to 69% in 2019. Overall, it can be seen that the levels of BIM adoption have increased significantly. After the mandate became active, the levels of BIM adoption reached more than 50%, excepting 2014 in which the levels of BIM adoption were 54% like in 2016. Also, it can be noted that the percentage of people aware and using BIM in 2019 is slightly lower than in 2018 (NBS, 2019).

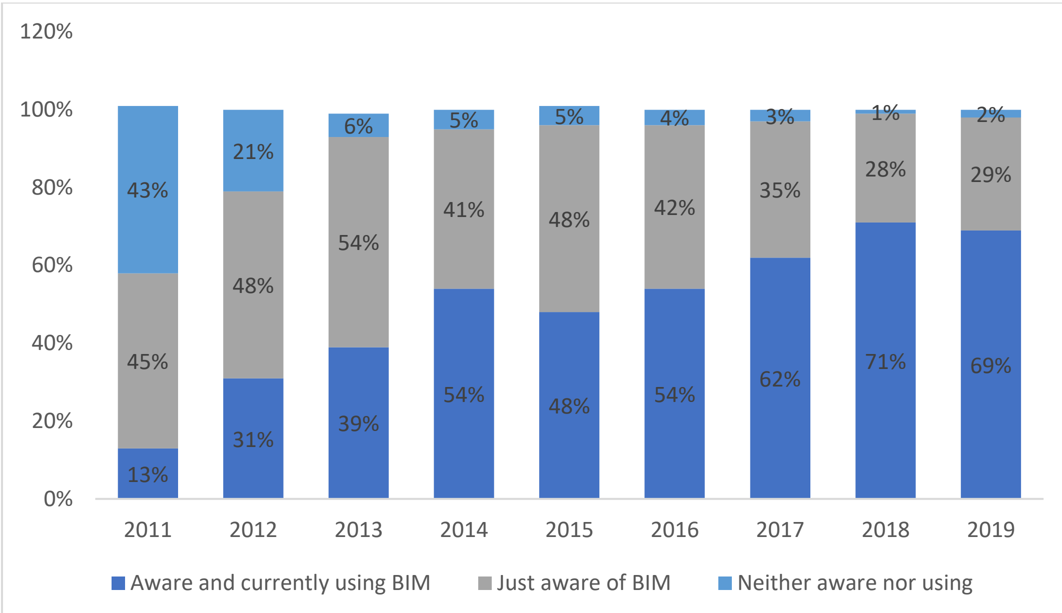


Figure 3.3 BIM adoption over time in the UK

Source: NBS (2019)

3.2.3.5 International standard: ISO 19650 series

To conclude with the implementation of BIM in the UK, it is worth mentioning the impact of the UK BIM Level 2 initiative worldwide. Following the UK mandate, international clients and asset owners, especially from Australia and the Middle East, have acknowledged its benefits and demanded the use of the management processes defined in the UK 1192 series. Many international organisations considered it was not fair to follow UK standards to win projects in their countries. Therefore, the global community approached the ISO and requested the UK 1192 series to be escalated to an international level. As a result, the ISO 19650 standard was created (Shillcock, 2019).

The ISO 19650 is an international standard designed to manage the information throughout the life cycle of a built asset using BIM. The standard encompasses the same concepts and high-level requirements of BIM Level 2 and is linked with the current UK 1192 standards (BSI 2018a). The ISO 19650 can be adopted as national standards by member states of ISO (Shillcock, 2019).

The first two ISO standards were published at the end of 2018:

- Building Information Modelling (BIM) BS EN ISO 19650–1 *Organization of information about construction works – Information management using building information modelling – Part 1: Concepts and principles;* and
- BS EN ISO 19650-2 *Organization of information about construction works – Information management using building information modelling – Part 2: Delivery phase of assets*.

In the UK these first two ISO 19650 standards substitute the BS 1192:2007 (Collaborative production of architectural, engineering and construction information - code of practice (+A2:2016)) and PAS 1192-2:2013 (Specification for information management for the capital/delivery phase of construction projects using building information modelling). These standards had to be withdrawn because there cannot be two standards at a national level (Shillcock, 2019). It is also planned that two other international standards will be issued in 2020 (BSI, 2018a), which will imply more changes to the current UK framework.

3.2.4 Singapore

Singapore is the most exceptional leader of BIM implementation in Asia and has one of the most rigid national BIM mandates (Cheng and Lu, 2015). BIM efforts in Singapore have mostly focused on simplifying and optimising the building's permit process for building projects (McGraw-Hill Construction, 2014b).

3.2.4.1 BIM initiatives from the Central government

In 1995 the Singapore's Ministry of National Development initiated the Construction Real Estate NETwork (CORENET) project to encourage and demand the use of IT and BIM for different levels of project's approval in the construction industry. The transition to BIM in Singapore started in 2001 when the paper-based submission was substituted by electronic submission with CORENET e-Plan Check, which explains Singapore's Automated Code Checking System (Wong *et al.*, 2010; McGraw-Hill Construction, 2014b; Cheng and Lu, 2015). Subsequently, various government entities took part in the e-submission systems, which demands BIM and IFC. Therefore, several BIM E-submission guidelines were produced and published to indicate submission requirements (Cheng and Lu, 2015).

In 2008, the Building and Construction Authority (BCA) led a multi-agency initiative via CORENET to create the world's first BIM electronic submission (e-submission). The new BIM e-submission system enhances the process for regulatory submission. Project members need to submit only one building model, including all the necessary information to comply with the requirements of a regulatory entity (BCA, 2011).

Later in 2010, the Building and Construction Authority (BCA) put into effect the BIM Roadmap as part of the government's plan of enhancing the productivity of the industry up to 25% by the 2020 decade. The roadmap establishes that by 2015, 80% of the construction industry would adopt BIM and the e-submission system for all new projects bigger than 5,000 squares (BCA, 2011; Cheng and Lu, 2015). Figure 3.4 presents Singapore's Five-year BIM roadmap.

2013	Mandatory BIM e-submissions for architectural approvals in new building projects over 20,000 square meters.
2014	Mandatory BIM e-submissions for engineering approvals in new building projects over 20,000 square meters.
2015	Mandatory BIM e-submissions for architectural and engineering approvals in new building projects over 5,000 square meters.

Figure 3.4 Singapore's BIM roadmap plan

Source: McGraw-Hill Construction (2014b)

Guided by the Real Estate Developer's Association of Singapore (REDAS), the BCA founded the BIM steering committee, an industry organisation to create BIM requirements guidelines (Cheng and Lu, 2015).

To raise awareness, the BCA organises several events related to BIM. For instance, BIM is a relevant theme in the most significant events in the industry "Singapore Construction Productivity Week (SCPW)". Several BIM competitions take place in this event: BIM Awards, to reward the work of project teams in the industry; BIM Shoot Out, directed to individual students from higher education institutions; and the International BIM competition, directed to student teams from higher education institutions in Singapore and overseas (BCA, 2016; Rooney, 2017). Other events comprehend the Government Symposium, with the participation of representatives and BIM experts of various countries (Rooney, 2017).

3.2.4.2 BIM initiatives from the construction industry

Major consulting engineering companies such as Arup and WSP have implemented BIM in their projects (Wong *et al.*, 2010). Arup has implemented BIM 2006 to develop projects in Singapore, becoming leaders in the use of digital design and coordination technologies. BIM was first used on the North-East Line project in Singapore. After this project, they have widely implemented BIM in numerous high-profile projects in the country, obtaining several awards (Chong, 2017). Arup has also gotten involved in other areas of BIM, such as the development of BIM Assessment Methods. In December 2014, they published the BIM Maturity Measure (BIM-MM) to assess and compare the maturity of BIM implementation in projects (Azzouz *et al.*, 2016).

3.2.4.3 BIM education and training

The BCA created the Building Construction Authority Academy (BCAA), which developed a training framework to ensure the acquisition of BIM knowledge to all the stakeholders in the industry (BCA, 2011). Also, the BCA has worked with several higher education institutions to create complete training programmes in the Architecture and Engineering curricula, including from workshops and seminars to competitions and internships. To raise awareness, they have delivered talks, seminars, and guest lectures on BIM in these institutions (BCA, 2011). As a result, numerous universities and polytechnics are offering BIM training and education in Singapore (McAuley *et al.*, 2017). By mid-2016, more than 2,500 full times and students and 8,5000 professionals had received BIM training. The BCAA delivers diploma and certification courses in different BIM specialities. They have also integrated BIM in a joint degree programme in BIM along with the Singapore Institute of Management (SIM). In 2015, they founded the Centre for Lean and Virtual Construction (CLVC) to motivate the use of the centre among higher education institutions and construction companies for training and experiential learning (Rooney, 2017).

3.2.4.4 Levels of BIM adoption

In 2013, the BCA carried out a survey which indicated that the adoption of BIM in the country had grown significantly from 25% in 2009 to 76% in 2013 after the establishment of BIM Roadmap. At the same time, the use has increased within construction companies. By 2013, 15% of the companies were using BIM in more than 50% of the companies' projects, compared to a 4% registered in 2012 (McGraw-Hill Construction, 2014b).

3.3 Late BIM adopter countries

3.3.1 Hong Kong

The implementation of BIM in Hong Kong started more than a decade ago; however, BIM is still not widely implemented (Chan, 2014; Cheng and Lu, 2015).

3.3.1.1 BIM initiatives from the public sector

The Housing Authority (HA), the institution responsible for the construction of public housings in Hong Kong is one of the early adopters of BIM. HA established a goal to apply BIM in all new projects by 2014 (BCA, 2011; Cheng and Lu, 2015). The HA has adopted BIM since 2006 in numerous public housing projects. They have developed their BIM standards, which are the first set of BIM standards in the country and have received high acceptance within the industry. They have also developed user guides, library component design guides, references, SAM (Standard Modelling Approach) to enhance model quality and allow automatic Quantity Take-Off (Fung, 2014; Cheng and Lu, 2015). They have conducted pilot studies in several areas such as Light simulation; Integration of Civil 3D, GIS and BIM; 5D BIM Studies; and Integration of BIM and RFID (Fung, 2014). ArchSD is another governmental department that created a BIM Development Unit in 2013 and has offered BIM training for its staff. They have used BIM in two pilot projects, namely Yau Ma Tei Theater Centre and Studios RTHK (Cheng and Lu, 2015).

The Hong Kong Construction Industry Council has adopted and explored the benefits of BIM (Cheng and Lu, 2015). Fung (2014) indicated that the BIM strategy implemented by the Hong Kong Construction Industry Council (CIC) is taking a push and pull approach. A push strategy, where project clients and asset owners are supported to adopt BIM; and a pull strategy, which consists in facilitating industry-wide buy-in and industry-wide ready. In 2013, the Hong Kong CIC started up a BIM Working Group to prepare a BIM roadmap and supervise the development of the CIC BIM standards

(Cheng and Lu, 2015). In 2014, the Working Group released the Roadmap for BIM Strategic Implementation in Hong Kong's Construction Industry. The roadmap is compound by 17 initiatives within nine broad areas: (1) Collaboration, (2) Incentive and proven benefit, (3) Standard and common practice, (4) Legal and Insurance, (5) Information Sharing and Handover, (6) Promotion and Education, (7) Compliant BIM Tool, (8) Audit and Risk Management, and (9) Global Competitiveness. Also, three immediate actions are recommended: Establishment of standards, Promotion and Training (Fung, 2014).

Since 2007, The Works Branch of the Development Bureau (DevB) established initiatives to progressively introduce BIM into the existing CAD Standard for Works Projects (Wong *et al.*, 2010) and started using BIM in different aspects (Cheng and Lu, 2015). In 2017, the DevB released the Technical Circular (Works) No. 7/2017 which establishes that from the 1st of January 2018, BIM delivery is mandatory for all public capital work projects to improve the design, construction project management, asset management and the productivity of the industry in general (Mott Macdonald, 2018).

3.3.1.2 BIM initiatives from the construction industry

3.3.1.2.1 BIM organisations

In 2009, a group of Hong Kong firms, stakeholders and experts in BIM tools created the Hong Kong Institute of Building Information Modelling (HKIBIM), the first professional institution to promote and enable BIM tools in the industry (Wong *et al.*, 2010). HKIBIM has set out several committees to support the implementation of BIM and offer a platform for communications for diverse stakeholders, including government departments and professional institutions related to construction (Wong *et al.* 2011b).

3.3.1.2.2 Construction organisations

As per Rosana Wong, executive director of the Yau Lee Group, a large contractor working in Hong Kong, the market in Hong Kong is mostly owner-driven. Premium general contractors are taking the lead in the implementation, but the adoption is usually one-shot because of special project requirements (McGraw-Hill Construction, 2014a). The MTR Corporation has implemented BIM in several projects. They demand their consultants and main contractors to hand in BIM deliverables according to their BIM standards and level of detail. A good project example from this company is the MTR XRL West Kowloon Terminus project (Cheng and Lu, 2015).

3.3.1.3 BIM Education and training

By 2017, there were a total of 19 BIM courses provided in universities and colleges as part of their curricula. Furthermore, the Vocational Training Council (VTC) including its members, the Institute of Vocational Education (IVE) and HKU Space, is delivering 20 BIM courses either as individual training programmes or as modules of their construction-related Higher Diploma programmes (Rooney, 2017).

The Hong Kong CIC is quite involved in education. They deliver 8 BIM courses through the Management and Safety Centre, which are directed to a wide range of people, from trainees to executives. The CIC works in conjunction with training institutions to increase the BIM competencies of professional, the leading labour force and model developers. Furthermore, they work with industry players to prepare BIM promotional activities along with industry players to raise BIM awareness and understanding in the industry (Rooney, 2017).

3.3.2 China

3.3.2.1 BIM initiatives from the Central government

China is a new BIM adopter that is catching up very quickly with the implementation of BIM (Cheng and Lu, 2015). The Ministry of Housing and Urban-Rural Development (MOHURD) is the primary government entity propelling the implementation of BIM in China. In 2012, they published the 12th National Five-Year Plan from the period of 2011 and 2015, which considered BIM topics, standards and a BIM framework (Cheng and Lu, 2015; De Cicco, 2018). Some local governments started to contemplate the development of BIM projects, BIM training programmers and BIM guides to meet the plan's requirements (Cheng and Lu, 2015). BIM had not been extensively adopted in both the public and private sectors because the BIM policy was perceived as a recommendation, not as a mandate.

Nonetheless, there has been much progress after the launch of the 13th Five-Year Plan (2016-2020). The new BIM policy of this plan has included the BIM lifecycle, and the government has been appointed as the main driver. The aim of this last plan is that by 2020, BIM will be "business as usual" (De Cicco, 2018).

The MOHURD has led the creation of various national standards supported by many organisations: the Unified Standard for BIM Application mainly developed by China BIM

Union; the Classification and Coding Standard and the BIM Delivery Standard, produced by the China Institute of Building Standard Design and Research; and the Storage Standard (Dodge Data & Analytics, 2015).

Parallel to national standards, local governments, have started to develop standards. For instance, the Beijing Municipal Commission of Urban Planning in partnership with Tsinghua University and relevant local design civil design institutes published the Beijing BIM Design Standard for Civil Building in 2014 (Dodge Data & Analytics, 2015).

3.3.2.2 BIM initiatives from the construction industry

In 2012, the China Academy of Building Research (CABR) along with other organisations created the China BIM Union aiming to develop BIM standards, promote BIM implementation and carry out research to benefit the local industry (Dodge Data & Analytics, 2015). Apart from the "Unified Standard for BIM Application", China BIM Union also contributed in a series of standards for P-BIM (Practice-based BIM) software applications and data exchange for specific activities (McAuley *et al.*, 2017).

3.3.2.3 BIM Education, training and research

Universities are creating BIM training programmes, and companies and educational institutions are encouraging BIM research (Dodge Data & Analytics, 2015). The China BIM Union has delivered numerous BIM education presentations and BIM workshops on BIM systems and applications. Furthermore, the China BIM Union has established a shared experiment centre on building internet and BIM in collaboration with Shenzen University (Rooney, 2017).

3.3.3 Latin America

The implementation of BIM is still nascent in Latin America compared to the global status of BIM and research on BIM implementation in this region is also limited. In their survey analysing the adoption of BIM in six regions of the world (Asia, Europe, Oceania, The Middle East/Africa, North America and South America), Jung and Lee (2015) concluded that South America was the least advanced continent in BIM adoption. In particular, the continent was the earliest BIM adopter with the lowest experience and BIM engagement level. Despite giving a general outlook of the status of BIM around the world, it is important to note that one limitation of this study is the small number of participants. Furthermore, the FIIC (Inter-American Federation of the Construction Industry) and INCONET (Inter-American Red of Innovation in Construction) conducted a survey in 2017 to gauge the implementation of BIM in the whole region (INCONET, 2017). According to the survey, Chile (32%), Brazil (27%) and Colombia (18%) are the primary users of BIM in the region; however, that can be attributed to the fact that 77% of the respondents of the survey were from these countries.

Despite their low levels of BIM adoption, there are already joint initiatives in this region. BIM Forum Latam is a collaborative forum that involves BIM entities from Argentina, Chile, Colombia, Costa Rica, El Salvador, Honduras, Mexico, Panama, Uruguay and Spain. Its most ambitious project is the creation of an international standard for Latin America (BIM Forum Chile, 2017); nevertheless, there has not been reported any actions regarding this yet. Thus far, the forum organises BIM conferences throughout the continent.

Following will be presented the study of BIM implementation in the most notable Latin American countries in the field: Brazil, Chile and Mexico.

3.3.3.1 Brazil

The Brazilian construction industry is among the largest markets in the world, accounting 2% of the global industry. Up to date, there are not any laws or decrees related to the use of BIM in the country. The interest in BIM in Brazil started in Academia. The first dissertations on BIM were presented in 1996 in the UFF (Universidade Federal Fluminense) (Kassem and Leusin de Amorim, 2015).

3.3.3.1.1 BIM initiatives from the public sector

In 2006, the Directorate of Military Projects (DOM), the entity responsible for the building and infrastructure projects in military organisations, developed the system OPUS to manage the life cycle of the built environment. OPUS (Unified system of the construction process) is an integrated system that controls the outcome phases of a project (e.g., acquisition, construction, demolition). It possesses information of more than 16,000 construction projects, which compound the portfolio of assets administered by the Brazilian Army. The system is web-based and can store 2D and 3D models of a variety of fonts and formats, with a Google map using a coordinate system. OPUS is considered a well-develop infrastructure system for BIM implementation, and therefore, represents a significant advancement for Brazil in terms of BIM (Kassem and Leusin de Amorim, 2015).

3.3.3.1.1.1 States

Some states of the country have driven the implementation of BIM in Brazil. In 2014, Santa Catarina became the first Brazilian state to issue decrees for the contracts of projects developed with BIM (Governo de Santa Catarina, 2014). As per Dors (2016), the goal of the Santa Catarina State Government is to demand BIM for the bidding of large projects from 2018. Following this goal, they have elaborated standards under the name "Cadernos BIM". Thus far, two versions have been released: Santa Catarina's Guidance notebook for the presentation of projects in BIM, in 2014; and the Collection of the implementation of BIM for builders and developers of the CBIC (Brazilian Construction Industry Chamber) in 2016 (Portal BIM Parana, 2018). Furthermore, in early 2015, the Secretariat of Infrastructure and Logistics (SEIL) of the Parana State Government defined in the "Plano de Metas 2015-2018" (Goals Planning, in English) the gradual adoption of the use of BIM as part of its processes and projects with the production of the "Plano de Fomento BIM" (BIM Development Plan, in English) (Barbosa, 2017).

3.3.3.1.2 BIM initiatives from Central Government

The implementation of BIM started to take national character when the Brazilian Federal Government created in June 2017 the CE-BIM (Strategic Committee of BIM Implementation), composed by seven ministries, from which the MDIC (Ministry of Industry, Exterior Trades and Services) is the leader (SECOVI-SP, 2017). From this initiative was created the strategy BIM BR, which aims to create a suitable environment for the diffusion and investment in BIM in the country. The plan comprehends nine objectives, including the mandatory use of BIM for public procurement. For that goal, a roadmap has been developed, which is divided into three phases: 2021, 2024 and 2028 (MDIC, 2018) (Refer to Figure 3.5):

2021	Mandatory BIM for new and refurbishment or extension projects (when considered necessary) contemplating the disciplines of architecture and engineering (structural, electric, plumbing and HVAC)
2024	Mandatory BIM for new and refurbishment or extension projects (when considered necessary) contemplating the requirements from the first phase along with cost estimation, constuction programme and as-built models.
2028	Mandatory BIM for new and refurbishment or extension projects (when considered necessary) contemplating all the actitivities of building life cicle, which includes the first and second phase along with facilities management after their completion.

Figure 3.5 BIM BR Roadmap

Source: MDIC (2018)

3.3.3.1.3 BIM initiatives from the construction industry

Industry associations created BIM a discussion group called BIM Interdisciplinary Group. Construction institutions also created the BIM Standards Committee which developed the first standards in the country: NBR 15965-1 – Construction information Classification System – Part 1.: Terminology and Structure, and Part 2.: Construction Objects Characteristics.

There are also isolated BIM implementation and development initiatives driven by professional associations and private companies that have contributed to the acquisition of BIM knowledge around professionals. Among the professional associations are Agesc (Asociation of Design Managers and Coordinators), AsBEA (Brazilian Architectural Firms Association), SindusCon (Construction Union). Companies comprehend software developers such as Autodesk, Bentley and PINI. Both types of organisations have arranged BIM workshops and courses, promoted and hosted BIM congresses and supported the development of BIM nation-wide (Souza, Wyse and Burratino, 2013).

Moreover, AsBEA has created the AsBEA Guidelines for Good practice in BIM. Up to now, there have been produced two parts: "Structuring of the company for the implementation of BIM" in 2013 and "Workflow in BIM projects: Planning and Execution" in 2015 (Manzione, 2016).

3.3.3.1.4 BIM education and research

Several universities are involved in BIM research: USP – University of Sao Paulo, UNICAMP - State University of Campinas, UPM – Mackenzie Presbiterian University, UFRGS – Federal University of Rio Grande do Sul, UFPR – Federal University of Paraná, UFBA – Federal University of Bahia, UFC – Federal University of Ceará (Souza *et al.* 2013). Despite the significant amount of BIM research undertaken in Brazilian universities, BIM has not been integrated into most of the curricula of Brazilian universities. In the post-graduate level, the situation is slightly different as there are more universities involved with BIM (Kassem and Leusin de Amorim, 2015).

The Brazilian Federal Agency for the Coordination for the Improvement of Higher Education created the BIM Brasil Network, which has been responsible for the insertion of BIM disciplines in academia and the promotion of BIM through workshop, courses and congresses (Souza *et al.,* 2013; McAuley *et al.*, 2017).

3.3.3.2 Chile

The implementation of BIM in Chile was first propelled in the private sector by a small group of private companies that offer external services for the creation and management of BIM models to professionals lacking this knowledge. The implementation of BIM started to spread in 2005. The industry reacted quickly to this revolution, and by 2010 there were dozens of companies offering BIM services externally (Loyola, 2014).

3.3.3.2.1 BIM initiatives from the Central Government

"Build 2025" ("Construye 2025" in Spanish) is the National Strategic Program of Sustainable Production and Construction that was created as part of the Agenda of the Productivity, Innovation and Growth presented by the Chilean President in 2014. The programme contemplates the current National Strategy of Sustainable Construction which aims to be a guiding tool to drive the integration of the sustainable development concept in the Chilean construction sector. Fifteen projects have been created within the programme to attain these goals, including the Plan BIM programme (Construye, 2016). Plan BIM is a 10-year programme which proposes the implementation of BIM for the development and operation of construction and public infrastructure by 2020. The programme is part of the Digital Transformation Committee of CORFO (Corporation of Production Development), the organisation that developed "Build 2025". The programme brings together the public sector, the private sector and Academia to create a collaborative environment for BIM adoption (Planbim, 2018). The plan establishes that from 2016, public projects will demand the use of BIM until being completely mandatory by 2020. From 2020, BIM will be gradually required for building's permit processes until being completely mandatory by 2025 (Soto, 2016) (Refer to Figure 3.6).

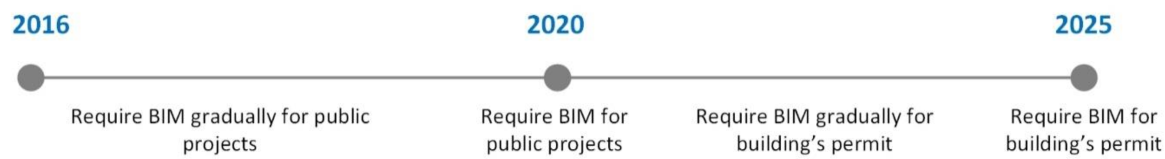


Figure 3.6 Plan BIM roadmap

Source: Soto (2016)

The actions of the Plan became official in the opening of the "XXXVII ENADE 2015" (National Encounter of Enterprises) when the president of the country announced that from 2016 BIM was going to be implemented in several ministries (BIM Forum Chile, 2015).

In June 2019 was published the "Standard BIM for Public projects". Plan BIM developed the standard based on the study of international regulations, standards and protocols and the collection of information from public projects. In terms of technology, standards from buildingSMART (Information Delivery Manual (IDM), Industry Foundation Classes (IFC), BIM Collaboration Format (BCF), International Framework for Dictionaries (IFD), Model View Definition (MVD)) and the British standard BS 1192-4:2014 for COBie were followed. The international standards ISO19650-1: 2018 and ISO19650-2: 2018 were used for general aspects. Lastly, American standards (AIA Document G202-2013, Level of Development Specification BIM Forum USA, BIM Planning at Penn State, VA BIM Guide), buildingSMART standards (BIM Basic Information Delivery Manual - version 1.0) and the British standard BS 1192:2007 were used for concepts development (Planbim, 2019).

3.3.3.2.1.1 International influence

The UK BIM experience has been influential in Chile's BIM journey. The Chile president expressed that with the National Strategic Program of Sustainable Production and Construction Chile is following the journey of the British Government on BIM (BIM Forum Chile 2015). An agreement between the Ministry of Public Works of Chile (MOP), CORFO, and the Department for Business, Innovation & Skills (BIS) through the former BIM Task Group was signed in 2016 to align the BIM public strategies of both countries (Planbim, 2018).

3.3.3.2.2 BIM initiatives from the construction industry

BIM Forum Chile is an entity that aims to disseminate BIM knowledge and good BIM practices in the country (BIM Forum Chile, 2018). The forum is the most active among all the forums and associations in the Latin American region.

3.3.3.2.3 BIM Education and training

In terms of education, Plan BIM is working with higher education institutions and technical centres to diagnose and build the workforce necessary to implement BIM in the country; define BIM roles and responsibilities; identify the knowledge required according to the BIM roles and responsibilities; and provide scholarships and co-funding for BIM education/training (Planbim, 2018).

By 2018, only 41% of the universities in Chile delivered BIM knowledge, mainly in the discipline of Architecture (Fernandez Gonzalez, 2018) (Refer to Figure 3.7 and Figure 3.8).

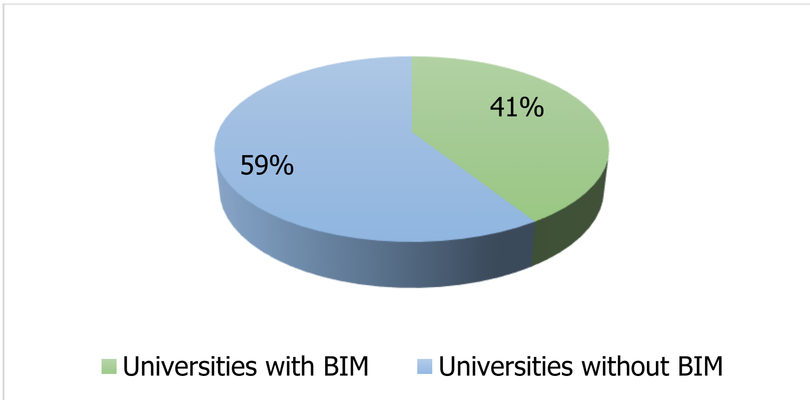


Figure 3.7 Presence of BIM in higher education institutions in Chile

Source: Fernandez Gonzalez (2018)

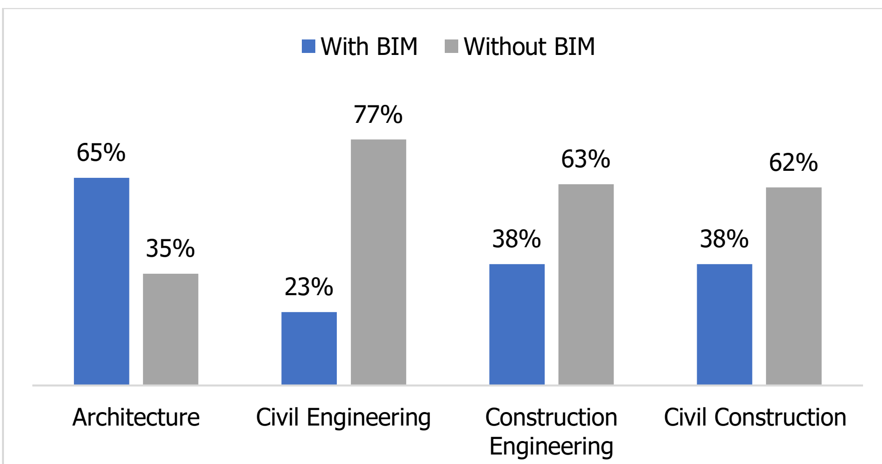


Figure 3.8 Presence of BIM in Higher education institutions in Chile per discipline

Source: Fernandez Gonzalez (2018)

By 2019, thanks to the Chilean BIM strategy, education and training had increased in the 42 universities that teach AEC disciplines, which represented an increase of 81% throughout the country.

Furthermore, 84% of the 106 programmes available in 2018 had incorporated BIM in mandatory courses within their curricula. This progress can be attributed to the diffusion efforts from Academia, public sector, private organisations, and software vendors through workshops, seminars and the development of 25 new continuing education courses, following the Matrix of BIM Roles (Rooney, 2019). The Matrix of BIM Roles is a document prepared by Plan BIM, which defines the BIM roles as well as the skills required within these roles to develop and operate BIM projects (Planbim, 2019). This document serves as guidance to academic institutions to prepare their BIM curricula (Rooney, 2019).

3.3.3.2.4 Levels of BIM adoption

National BIM surveys have been conducted in Chile every three years since 2013 to analyse the use of BIM in the private sector of the Chilean construction industry (Loyola, 2013; Loyola, 2016; Loyola, 2019). As presented in Figure 3.9, the percentage of BIM users in Chile is increasing gradually. From 2013 to 2016 the percentage of regular BIM users slightly decreased from 23% to 22%; while the rate of non-users significantly reduced from 61% to 47%. In 2019 was conducted the first survey after the mandate started to be effective in 2016. The results show a significant growth of regular BIM users (34%); nonetheless, the amount of occasional users and non-users combined is still quite high compared to the regular users. Thus far, the gradual demand for BIM in public projects has had a positive impact on the Chilean construction industry. It would be interesting to see how the levels of BIM adoption will be once the mandate becomes mandatory for, both public and private projects in 2025.

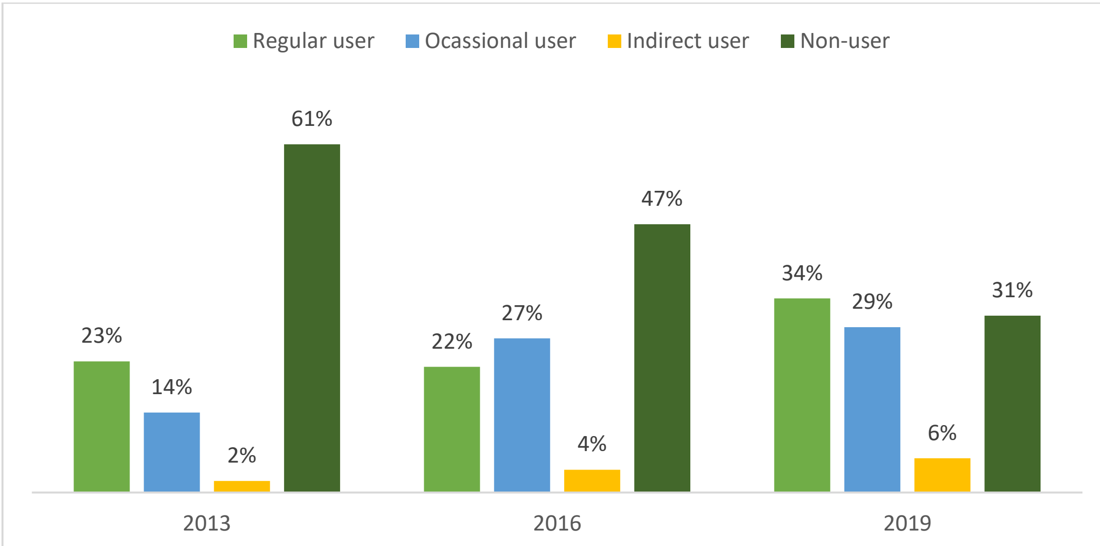


Figure 3.9 Comparison of the results from the National BIM survey in Chile on BIM adoption.

Source: Loyola (2019)

3.3.3.3 Mexico

3.3.3.3.1 BIM initiatives from the public sector

BIM has not been mandated in Mexico yet, but regulations have already been created. In 2016, ONNCCE (National Organisation for Standardisation and Certification of Construction and Building, in English) proposed and launched a BIM regulation for public consultation. The objective of this regulation was to establish the specifications to implement BIM in construction projects through the elaboration of a follow-up execution plan (Hirata, 2016). Later, in 2017 was declared by the Economy Secretariat that the regulation was going to be valid 60 days after that declaration. The name of the regulation is "NMX-C-527-1-ONNCCE-2017, Construction Industry-Building Information Modeling-Specifications-Part 1: Execution Plan for Projects" (Esteban, 2017). The regulation is available on the ONNCCE website but has the limitation that needs to be purchased.

The FIC (Foundation of the Construction Industry) is an institution created by the Mexican Construction Industry Chamber which seeks to improve the competitiveness of companies through the implementation of technology and, in the last years, has led and promoted the implementation of BIM in the country (ASOBIM, 2016). The FIC delivers BIM courses and created in 2014 the BIM Forum Mexico, an entity compound by organisations interested in speeding up the implementation of BIM in the country (FIC, 2015; FIC, 2018).

3.3.3.3.2 International influence

The global consulting company Arcadis, in the name of the United Kingdom embassy in Mexico City, elaborated a report as a contribution to the development of strategies for the implementation of BIM in the country. The report evaluated the BIM status in Mexico and identified that the initial development of the BIM capacity in Mexico would be led by suppliers, designers and contractors (Rawlinson, 2015).

The Mexican construction industry is also experiencing the development of an important BIM project: The New International Airport of Mexico City developed by Fosters + Partners, which will be one of the largest and sustainable airports in the world. The implementation of BIM has been identified as fundamental for the sustainable and terminal design objectives of this project. The airport was awarded the first place in infrastructure in the 5th AEC Excellence Awards 2017 (Autodesk, 2017).

3.4 Discussion on the implementation of BIM worldwide

Table 3.4 shows a summary of the study of BIM implementation in the selected countries. The table presents the starting point of BIM implementation in the country, as well as their key initiatives/contributions and key players discussed in this study.

Table 3.4 Summary of key aspects of the implementation of BIM in the early and late BIM adopter countries

Early BIM adopters	
United States of America	
Starting point: National 3D-4D-BIM program by GSA in 2003	
Key initiatives/contributions	• 2003: National 3D-4D-BIM Program BY GSA. • 2006: "Building Information Modelling: A Road Map for Implementation to Support Military Construction (MILCON) Transformation and Civil Works Projects within the U.S. Army Corps of Engineers" by USACE. Updated in "The US Army Corps of Engineers Roadmap for Life-Cycle Building Information Modeling (BIM)" • 2008: LOD framework by AIA.
Key players	• GSA (General Services Administration) • USACE (United States Army Corps of Engineers • AIA (American Institute of Architects) • AGC (Association of General Contractors of America) • NIBS (National Institute of Building Sciences)
Finland	
Starting point: Development of BIM projects by Senate properties since 2001	
Key initiatives/contributions	• 2007: Mandate the use of BIM by Senate properties • 2012: Finnish National BIM Guidelines (COBIM) by Senates properties
Key players	• Senate properties
Norway	
Starting point: Digital e-submissions in the Norwegian Building Authority and the Map Authority of Norway in 2000	
Key initiatives/contributions	• 2010: Commitment to BIM by the Norwegian government • 2010: Mandate IFC-compatible BIM for new projects by Statsbygg
Key players	• Norwegian government • Statsbygg
Denmark	
Starting point: *"Will to growth"* competitiveness package by the Danish Government in 2002	
Key initiatives/contributions	• 2007: Digital Construction project by the Danish government to require the use of BIM in governmental projects. • 2011-2015: Project cuneco by Molio (former bips). Key contribution: Cuneco Classification System (CCS)
Key players	• Danish government

	• Construction Information Centre Molio (former bips)
United Kingdom	
Starting point: BIM mandate by the Cabinet Office, Government of the United Kingdom in 2011	
Key initiatives/contributions	• 2011: Cabinet Office mandates the implementation of BIM Level 2 in public projects by 2016. • UK 1192 series • 2011: Creation of BIM Academic Forum by the former BIM Task Group • Annual surveys to gauge the status of BIM in the UK since 2011 by the NBS
Key players	• Government of the United Kingdom • Former BIM Task Group • BSI (British Standards Institution) • NBS (National Building Specifications) • CIC (Construction Industry Council) • AEC-UK • UK BIM Alliance
Singapore	
Starting point: Creation of CORENET project by the Singapore's Ministry of National Development in 1995	
Key initiatives/contributions	• 2008: World's first BIM electronic submission (e-submission) by BCA along with CORENET project. • 2010: Five-year BIM roadmap for the adoption of BIM and the e-submission system by BCA. • Creation of the BIM Steering committee by BCA.
Key players	• BCA (Building and Construction Authority)
Late BIM adopters	
Hong Kong	
Starting point: Use of BIM in the Housing Authority (HA) since 2006	
Key initiatives/contributions	• 2009: Creation of the professional institution HKIBIM (firms, stakeholders and BIM experts) • 2014: BIM Mandate in all new projects by the HA. • 2013: Creation of a BIM Working Group for a roadmap • 2014: Roadmap for BIM Strategic Implementation in Hong Kong's Construction Industry • 2017: Technical Circular (Works) No. 7/2017 by the DevB to set BIM as mandatory from the 1st of January 2018 in all public capital work projects
Key players	• HA (Housing Authority) • HKIBIM (Hong Kong Institute of Building Information Modelling) • DevB (The Works Branch of the Development Bureau)
China	
Starting point: the 12th National Five-Year Plan by MOHURD in 2012	
Key initiatives/contributions	• 2012: National Five-Year plan (2011-2015) by MOHURD. • 2012: Creation of China BIM Union by the China Academy of Building Research (CABR) to develop standards, research, and promote BIM implementation.
Key players	• MOHURD (Ministry of Housing and Urban-Rural Development) • China BIM Union

Brazil	
Starting point: Academia. Academic dissertations on the subjects since 1996	
Key initiatives/contributions	• 2006: Development of the OPUS system by the Directorate of Military Projects (DOM) • 2014: Santa Catarina State Government issued decrees for the contract of projects developed with BIM • 2015: BIM Development Plan (Plano de Fomento BIM in Portuguese) by the Secretariat of Infrastructure and Logistics (SEIL) of the Parana State Government • 2017: Creation of the CE-BIM by the Brazilian Federal Government • Strategy BIM BR which includes the mandatory use of BIM for public procurement in a period from 2021-2028.
Key players	• Brazilian Federal Government • MDIC (Ministry of Industry, Exterior Trades and Services) • DOM (Directorate of Military Projects) • Santa Catarina State Government • Parana State Government
Chile	
Starting point: Implementation in the private sector (2005-2010)	
Key initiatives/contributions	• 2014: Announcement of the National Programme "Build 2025" (Construye 2025) by the Chilean president. • Plan BIM: 10-year programme within "Built 2025" to implement BIM gradually from 2016 to 2025. • 2019: Publication of "Standard BIM for Public projects."
Key players	• Central government • CORFO (Corporation of Production Development, in English) • BIM Forum Chile
Mexico	
Starting point: Creation of BIM Forum Mexico in 2014	
Key initiatives/contributions	• 2016: Publication of BIM regulation for public consultation by ONNCCE 2017: Validation of the regulation mentioned above under the name Construction Industry-Building Information Modeling-Specifications-Part 1: Execution Plan for Projects. • Important BIM project: Important project: New International Airport of Mexico City
Key players	• FIC (Foundation of the Construction Industry) • BIM Forum Mexico • ONNCCE (National Organisation for Standardisation and Certification of Construction and Building, in English)

Overall, the review of literature on the implementation of BIM worldwide indicated that when the central government and public sector take the lead through a BIM mandate, many players from the public sector, Academia and the industry act accordingly allowing higher levels of BIM implementation and diffusion. According to Sanchez, Kraatz and Hampson (2014), global experience has shown that the industry reacts when the government establishes a clear leadership for BIM implementation (Sanchez, Kraatz and Hampson, 2014). That is the case of the UK, whose mandate has had a significant influence on the interest in BIM in the country (Miettinen and Paavola, 2014). Furthermore, national leadership and coordination driven by governmental entities improves productivity and elude issues generated by fragmented and disconnected approaches (Smith, 2014c).

It could be noted that when the lead comes from the central government, the influence is nationwide, and other public organisations can participate and be assigned to perform specific roles to attain the national BIM goals. An excellent example in this regard is the former BIM Task Group and the Centre for Digital Built Britain in the UK. On the other hand, when public organisations take the lead, it was noted that their scope of action is smaller as it is only applicable to these organisations. Nonetheless, they can become powerful enough to mobilise a whole industry, as presented with several public BIM initiatives in the USA.

Initiatives from Academia are also vital. As indicated by Smith (2014), BIM education, training and research are essential to motivate the implementation of BIM and the evolution of the industry. The study on BIM implementation worldwide has demonstrated how education institutions have propelled BIM by providing BIM education and conducting research with the support of the government (e.g.

Singapore,) or by own initiative (e.g. Brazil). The study has also shown that educational institutions have the power to start the diffusion of BIM in a country, like in Brazil, whose first manifestations of BIM started through research.

Furthermore, industry players have also taken the lead to drive the implementation through different initiatives. In the USA, two good examples are the professional bodies AIA and AGC, whose involvement includes from standardisation efforts to BIM promotion. Construction organisations have also driven the implementation, primarily through adoption. They have also been vital in diffusing the implementation of BIM in a country. For instance, the implementation of BIM in Chile was initially driven by private companies, and nowadays, the country has a BIM mandate set to start in 2020.

From the above discussion, it was observed how the global status of BIM has a relevant influence in country-wide BIM implementation. Succar and Kassem (2015) denoted that governments and authorities implementing BIM worldwide can pressure similar entities in other markets to implement BIM through what is known as top-down diffusion. The main example in that respect is the international approach proposed by the new ISO 19650, which emerged from the request of other countries that recognised the benefits of BIM Level 2 in the UK but demanded an approach that could be implemented in their countries. Now, the ISO 19650 can be implemented as national standards in member states of ISO, which enhances communication and collaboration in the international community. Another pattern of global influence was noted in Chile, which has openly followed the steps taken in the UK for its National BIM strategy. This approach is suggested by Imoudu Enegbuma, Godwin Aliagha and Nita Ali (2014). They stated that since BIM adoption is hindered by several challenges globally, new BIM adopters should study the adoption of BIM in mature markets to identify and elude the shortcomings they have gone through.

The studied patterns of BIM implementation worldwide allowed the identification of the critical enabling factors for country-wide BIM implementation: Central government/public sector leadership, Academia leadership, and the Industry leadership to enable country-wide BIM implementation. Furthermore, Global BIM influence is also considered as part of these factors because of how the implementation of BIM in other countries and the status of BIM globally have a positive impact in the implementation of BIM in a country.

Similarly, this review of the literature identified the importance of collaboration among different players for the implementation and diffusion of BIM. For instance, the collaboration between Academia and Industry players was noted with the collaboration between China BIM Union and with Shenzen University to develop a research centre on BIM (Refer to Section 3.3.2). Collaboration within Academia is also of great importance to build BIM capacity. As mentioned earlier, the Learning Outcome Framework was created by the BIM Academic Forum, a group of representatives of UK universities established and supported by the former BIM Task Group. Moreover, the BCA Academy from Singapore has worked closely with higher education institutions to support the insertion of BIM in university curricula. Lastly, it was evident that the collaboration between government/public organisations from different countries can contribute to the implementation of BIM. For example, GSA in the USA has collaborated with the Association of Finnish Contractors in Finland and other players to develop openBIM standards (Wong *et al.*, 2010).

Another example is the agreement between the Ministry of Public Works of Chile (MOP), CORFO, and the Department for Business, Innovation & Skills (BIS) in the UK to develop strategies in Chile aligned to the ones in the UK (Planbim, 2018). Public entities from the United Kingdom, Hong Kong, Singapore have also registered to international bodies such as BuildingSMART international as part of their BIM initiatives (Harris *et al.*, 2014). Regarding this, Wong *et al.* (2010) pointed out that national BIM initiatives should be promoted, presented and developed in cooperation with stakeholders inside and outside the country.

The literature on the topic of BIM implementation also emphasises the need for collaboration. Wong *et al.* (2010) posited that the public and private sector should work collaboratively to provide a proper environment for the implementation of BIM. Smith (2014c) further stated that government organisations require the assistance and collaboration of key players in the industry such as major private sector clients, contractors and industry/professional bodies to lead the implementation of BIM.

Moreover, Bui *et al.* (2016) suggested that besides government support, spreading BIM knowledge to construction organisations is an effective method to speed up BIM diffusion which can be realised through the collaborative work of professional bodies, industry members and Academia. Lastly, Liu *et al.* (2015) indicated that the BIM implementation process includes the government, Academia and the industry, which can be integrated and form a tripartite collaboration with proper support from the government. From all the countries studied, the UK is the one with the strongest tripartite collaboration thanks to their robust BIM mandate and the extensive support offered by the government and their organisations.

Figure 3.10 presents the critical-enabling factor identified with this review of the literature. Central government/public sector leadership, Academia leadership and Industry leadership are enclosed together as the critical enabling-factors of BIM implementation within a country, in what is named *BIM Environment Country-wide*. On the other hand, Global BIM influence is contained in what is called *BIM Environment Worldwide* because of its broader scope. Furthermore, the need for collaboration among these players to enable the implementation of BIM in a country is illustrated, emphasising that the ideal collaboration should take place among the Central government/Public sector, Academia and the Industry: tripartite collaboration. Since the Central government and Public sector leadership is the main driving force, it is in the top of the hierarchy. In contrast, Academia and Industry leadership are presented below. Global BIM influence (BIM Environment Worldwide) is also shown because of how other countries can potentially inform the implementation of BIM in a country through influence, collaboration and guidance as reflected in the literature.

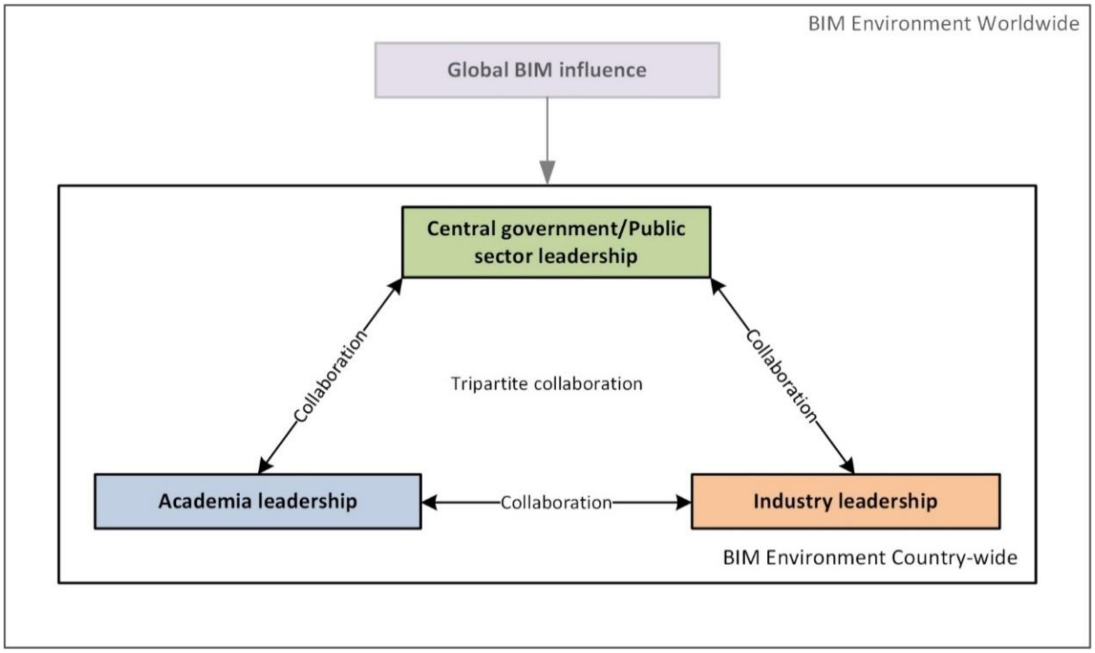


Figure 3.10 Critical enabling factors for country-wide BIM implementation

3.5 BIM in the Dominican Republic

As previously stated, there is a paucity of research on BIM implementation in the D.R. By the time this research started, the only reference in terms of practical BIM implementation in the country was a master's dissertation from the University of Wolverhampton under the name *"BIM implementation in the Dominican Republic: a comparative analysis with the UK process"* (Despradel, 2015). The dissertation presented two projects in the Dominican Republic in which BIM was implemented: a university's building and the construction of a hospital, both located in the Distrito Nacional, capital of the country.

Moreover, the Dominican government has not publicly expressed any interest in mandating the use of BIM in the Dominican Republic. Therefore, there is no clear guidance as to how BIM can be implemented in the country, which is the case of many emerging markets worldwide (Ahuja *et al.*, 2018). Nonetheless, there were found initiatives in the country that can pave the way for this scenario in the future: the project "Electronic government", the programme "Digital Republic", the project "Connected city councils" and the E-submission for building's permit in Ministry of Public Works and Communications (MOPC).

- **Electronic Government *("Gobierno Electronico" in Spanish)***

The project "Electronic Government" was issued in 2007 through Decree No. 229-07 (Fernandez*,* 2007). This project aims to improve national competitiveness with an environmental responsibility by providing transparent high-standard services to Dominican citizens based on an inter-connected government and the development of ICT. It includes different topics such as e-Politics, e-Transparence, e-Participation, e-City councils, e-Education, e-Tourism, and e-Investigation (Portal Oficial de la Republica Dominicana, 2016).

- **Digital Republic *(Republica Digital in Spanish)***

"Digital Republic" is a governmental programme set for the presidential term 2016-2020 that seeks to guarantee access to ICT to all Dominican citizens to reduce the current digital gap and provide better services to the citizens. This initiative is based on four core strategies: Education; Access; Productivity and employment; and Open and transparent digital government (Refer to Figure 3.11) (Ministerio de la Presidencia, 2016).

Education	**Access**	**Productivity and employment**	**Open and Transparent Digital Government**
•Better learning with the availability of more resources for teaching, in a pleasant, rewarding and personalised environment	•Promote the implementation of ICT infrastructure at a national level, guaranteeing broad access to ICT	•Improve levels of competitiveness among SMEs entrepreneurs, connecting Micro, Small and Medium Enterprises to Digital Economy	•Guaranteeing more agility, competitiveness and transparency in public services

Figure 3.11 Core strategies of the Digital Republic programme

Adapted from Ministerio de la Presidencia (2016)

- **Connected city councils**

"Connected city councils" is one of the five projects contained within the "Open and Transparent Digital Government" strategy which consists of digitalising city councils through the creation of web pages thus they can offer municipal services through the internet. To date, 80 city councils have been "connected" through this strategy (Ministerio de la Presidencia, 2016).

- **E-submission for building's permit in Ministry of Public Works and Communications (MOPC)**

Another significant advancement has been the creation of a portal web for the Department of building's permit of the Ministry of Public Works and Communications (MOPC), which will be available since the 1st of November of 2018. The department is involved in an internal digitisation process seeking to shorten the duration of the building's permit process. Furthermore, with this method, professionals will be able to do remotely a process that was only done in person (Arias, 2018; MOPC, 2018).

In conclusion, the status of BIM in the Dominican Republic is currently undocumented. Therefore, initiatives towards BIM and its position as to BIM implementation around the world need to be explored through a qualitative inquiry.

3.6 Summary

The discussion in this chapter was based on a literature review on BIM implementation worldwide, where initiatives to drive the implementation of BIM in different countries are highlighted. The chapter also presented the latest reports of levels of BIM adoption to see if the strategies have had a positive impact on the use of BIM in the countries. By exploring the implementation of BIM in various countries, it was possible to see the nature and scale of different initiatives towards BIM implementation within a country. First, it could be noted that the strongest initiatives to drive BIM implementation come from the central government and public sector.

Furthermore, Academia and industry players can also take the lead to drive the implementation and diffusion of BIM within a country. Lastly, it could be observed how the global status of BIM is also relevant as international collaboration has also been vital in driving the implementation of BIM in various countries. These findings allowed the researcher to identify critical enabling factors for country-wide BIM implementation, which were summarised into the following: Central Government and public sector leadership, Academia leadership, Industry leadership and Global BIM influence. Central Government and public sector leadership, Academia leadership and Industry leadership are enclosed in what is named BIM Environment country-wide. In contrast, Global BIM influence is included in what is described as BIM Environment Worldwide due to its broader scope. Moreover, the need for collaboration among these players for the implementation and diffusion of BIM was also stated, highlighting that the ideal collaboration should be realised among players from Central Government and public sector, Academia and the Industry leadership in what is called tripartite collaboration. In its broader scope, Global BIM influence allows the collaboration and guidance on BIM in different countries.

This chapter concludes by providing an overview of the status of BIM in the D.R., from which there is limited literature available. This gap in knowledge has presented an opportunity to investigate the implementation of BIM in the D.R. through this qualitative study. Research findings on the subject are discussed in Chapter 5, 6, 7 and 8.

The next chapter (i.e. Chapter 4) describes the research methodology adopted for this study.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Introduction

This chapter discusses the research methodology used in the present study. It first introduces the aspects considered for the selection of the research approach, namely philosophical worldview, research design and research methods following Creswell and Poth's (2017) framework of research. Then, a detailed explanation of the research strategy is provided, highlighting the need for a preliminary study, sampling considerations, the data analysis process, and how its trustworthiness was evaluated. To finalise, it discusses relevant information about the two phases of the research process: the preliminary study and the main study.

4.2 Selection of research approach

Research approaches are plans and processes for conducting research which extend from broad assumptions to specific methods for data collection, analysis and interpretation (Creswell, 2014). The literature on research methods shows that there are three types of research approaches: qualitative, quantitative and mixed methods (Creswell, 2014; Saunders, Lewis and Thornhill, 2017). According to Creswell (2014), the selection of the research approach for a study should be informed by three essential aspects: (1) the philosophical worldview assumptions of the researcher, (2) the procedures of inquiry, namely research design, and (3) the research methods for data collection, analysis and interpretation.

To select the most suitable approach for this research, this study has adopted the framework for research developed by Creswell and Poth (2017) (See Figure 4.1). The elements considered from this framework and related to this research are explained in the following sections.

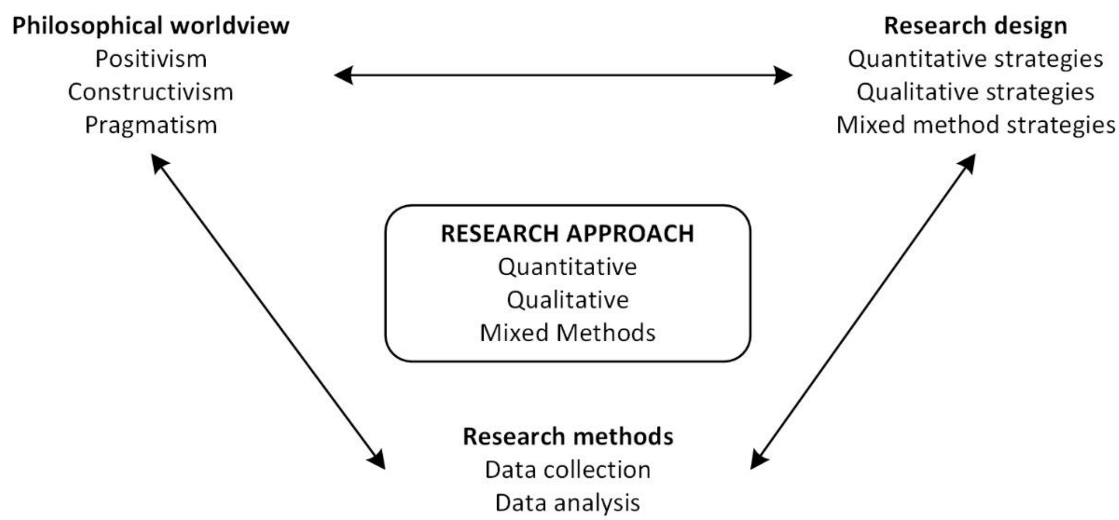


Figure 4.1 Framework for research

Adapted from Creswell and Poth (2017)

4.2.1 Philosophical worldviews

According to Creswell (2014), philosophical worldviews are "a basic set of beliefs that guide action" (Guba, 200, p.17). Other authors have used the terms paradigms, epistemologies and ontologies, or broadly conceived as research methodologies to refer to philosophical worldviews. Although philosophical worldviews are generally hidden in research (Slife and Williams, 1995), they need to be identified because they inform the research strategies and methods adopted by the researchers (Creswell, 2014).

There is an open-ended debate about the philosophical worldviews or beliefs that researchers adopt (Creswell, 2014). Positivism and interpretivism are two dominant worldviews in research (Fellows and Liu, 2015). More recently, pragmatism has emerged as a third philosophical worldview alternative (Wicks and Freeman, 1998; Goldkuhl, 2012). These major philosophical worldviews will be succinctly explained. For that, this study will introduce first the concept of research assumptions, which are vital in understanding and selecting the philosophical worldviews of research.

According to Saunders, Lewis and Thornhill (2017), researchers will make several types of assumptions at every stage of their research. A set of well-thought and rational assumptions will form a solid research philosophy that will, in turn, serve as a basis for the methodological choice, research strategy, and data collection techniques and analysis processes. There are three types of research assumptions to differentiate research philosophies: Ontology, epistemology and axiology. Ontology refers to the assumptions about nature of reality and its characteristics (Creswell and Poth, 2017; Saunders, Lewis and Thornhill, 2017): claims on what exists, what it looks like, what units make it up and the interaction between these units (Guba and Lincoln, 1994). Epistemology relates to assumptions about knowledge, what is acceptable, valid and authentic and how knowledge can be communicated to others (Saunders, Lewis and Thornhill, 2017). It recognises the theory of knowledge, specifically concerning its methods, validation and the possible means of gaining knowledge in the assumed reality (Sutrisna, 2009). To conclude, axiology concerns the role of values and ethics in the research process (Saunders, Lewis and Thornhill, 2017). It refers to how researchers are aware of their values, attitudes, and biases and recognises how these might proceed in research praxis about (a) what questions are asked or not asked in our research; (b) what kind of data are or are not gathered; and (c) the type methods, measurement, analysis and interpretation that built our understanding of the research process (Hesse-Biber, 2012).

This research adopted a pragmatic worldview. Following, the major philosophical worldviews considered for this study will be briefly explained emphasising each of the research assumptions described above. The rationale as to why a pragmatic worldview was adopted will be subsequently explained.

4.2.1.1 Positivism

Positivism identifies only non-metaphysical facts and observable phenomena; therefore, it is entirely related to rationalism, empiricism and objectivity (Fellows and Liu, 2015). Positivism firmly focuses on scientific empiricist approach to generate pure data and facts which are not affected by human interpretation or bias (Saunders, Lewis and Thornhill, 2017). Hence, it has a strong connection with quantitative approaches (Fellows and Liu, 2015). Ontologically, positivism state that reality is experienced the same way by each individual. Epistemologically, positivism supports the adoption of methods of natural science to study the truth (Sustrina, 2009). Furthermore, in their axiological position, positivist researchers would try to be neutral and independent from their research and data to avoid bias in their findings. Therefore, research is conducted as far as possible in a value-free way (Saunders, Lewis and Thornhill, 2017).

4.2.1.2 Interpretivism

On the other hand, interpretivism or constructivism is a non-positive approach to research (Sefotho, 2015). It recognises that reality is created by the people involved (Fellows and Liu, 2015). Interpretivism is commonly perceived as an approach to qualitative research (Creswell, 2014), although it can be adopted in quantitative research (Fellows and Liu, 2015). Ontologically, interpretivist/constructivist researchers believe that everyone builds reality differently. Epistemologically, the researchers or observers separate the objects of natural science from the actors and develop their own "truth" of seeing the world (Sutrisna, 2009). An axiological assumption of interpretivism is that the researcher acknowledges their interpretation of research materials and data, and their values and beliefs are crucial in the research process. Besides assuming an empathetic position, the researcher needs to enter the social world of the research participants and understand that world from their perspective (Saunders, Lewis and Thornhill, 2017).

4.2.1.3 Pragmatism

In pragmatism, there is interest in using what works and what provides solutions to the research (Creswell and Poth, 2017). The ontological assumption of pragmatic researchers is that reality matters as practical effects of ideas. Their epistemological position and knowledge are valued for facilitating actions to be executed successfully. For a pragmatist researcher, research begins with a problem, and the aim is to provide practical solutions that influence future practice. In terms of axiology, researchers' values encourage the reflexive process of inquiry. This process starts with the doubt and perception that something is incorrect or out of place, which re-creates belief after the problem has been addressed. An axiological implication of pragmatism is that the research problem and the research questions are the central stimuli to develop the research design and strategy. The research question consecutively would probably include the pragmatic emphasis of practical outcomes (Saunders, Lewis and Thornhill, 2017).

Pragmatists admit that there are many different forms to understand the world and conduct research. However, that does not infer that they always adopt multiple methods. Assuredly, they select the method(s) that make possible the collection of accurate, well-founded, reliable and essential data that progress the research (Saunders, Lewis and Thornhill, 2017).

To conclude, Table 4.1 presents a comparison between the three philosophical worldviews in regards to their research assumptions and their typical research methods.

Table 4.1 Comparison of the major philosophical worldviews considered in this study

Source: Saunders, Lewis and Thornhill (2017)

Ontology	**Epistemology**	**Axiology**	**Typical methods**
	Positivism		
• Real, external, independent • Only one reality (universalism) • Granular (things) • Organised	• Scientific methods • Observable and measurable facts • Law-like generalisations • Numbers • Causal explanation and prediction as a contribution	• Value-free research • Research is detached, neutral and independent of what is being researched • Researcher keeps an objective position	• Typically deductive, highly structured, large samples, measurement, usually quantitative, methods of analysis but a range of data can be analysed
	Interpretivism		
• Complex, rich • Socially constructed	• Theories and concepts too	• Value-bond research	• Typically inductive. Small samples, in-

through culture and language • Multiple meanings, interpretations, realities • Flux of processes, experiences and practices	simplistic • Focus on narratives, stories, perception and interpretations. • New understandings and worldview as contribution	• Researchers are part of what is researched, subjective • Researcher interpretations key to contribution • Researcher is reflexible	depth investigations, qualitative methods of analysis, but a range of data can be interpreted.
Pragmatism			
• Complex, rich, external • Reality is the practical consequences of ideas • Flux of processes, experiences and practices	• Practical meaning of knowledge in specific contexts • 'True' theories and knowledge are those that enable successful action • Focus on problems and relevance • Problem-solving and informed future practice as a contribution	• Value-driven research • Research started and supported by the researcher's doubts and beliefs. • Researcher is reflexive	• Following the research problem and research question • Range of methods: mixed, multiple, qualitative, quantitative, action research • Emphasis on practical solutions and outcomes

4.2.1.4 The philosophical worldview adopted

From the research problem, as well as the research questions and aim and objectives could be inferred that an interpretivist worldview would be adopted for this study. Nonetheless, the way in which the researcher had planned to address the research problems are more in line with research assumptions within a pragmatic approach. Saunders, Lewis and Thornhill (2017) argued that when a research problem does not recommend a certain kind of knowledge or method that should be used, it demonstrates the pragmatist's view that is viable to work with different types of knowledge and methods. Moreover, pragmatism highlights that each aspect of the research intrinsically concerns decisions about which goals are most relevant and which methods are the most appropriate (Morgan, 2014). The research assumptions made by the researcher demonstrates the focus on what would work to conduct this research and fulfil its aim. The pragmatic ontology is reflected in the flux of processes throughout the research journey and the practical consequences of ideas. Different methods were adopted and evaluated to either accept them or discard them conforming the aim of the research. Therefore, the first research phase (preliminary study) is different from the final (main study) (Refer to Section 4.4 and 4.5 for more details on these phases). The pragmatist epistemology is illustrated in the way in which the researcher focused mainly on the research problem and adopted the most appropriate methods to fulfil this aim. Lastly, the pragmatic axiological position is observed in the way in which the values of the researcher have driven the research process. The considerations during the research process as to what would not work (i.e. discard the study of construction projects) and the decision of including topics that emerged during the research process (i.e. BIM education in the country) confirm this position (See more details in Section 4.4.5).

4.2.2 Research design

After defining their philosophical worldview, researchers need to determine the research strategy and which research methods will be adopted for the collection and analysis of data (Creswell, 2014). The three standard research designs are qualitative, quantitative and mixed methods, from which qualitative was the research design adopted for this study.

The three major research designs will be described, and the rationale as to why a qualitative design was adopted will be subsequently explained.

4.2.2.1 Qualitative research

Qualitative research is an approach that allows researchers to explore and understand the connotation individuals or groups give to a social or human problem. The research process consists of emerging questions and procedures. Data is usually gathered in the participant's environments, and data analysis is inductively generated from specific to general themes and the researcher understanding the meaning of the data (Creswell, 2014). Many types of qualitative research can start with an inductive approach, which aims to build a theory or develop a more in-depth theoretical outlook than the existing in the literature. Nonetheless, qualitative research can also start with a deductive approach using qualitative processes to test a current theory (Saunders, Lewis and Thornhill, 2017). Qualitative research has been considered suitable to study complex issues and allow rich findings while acknowledging the researchers' impact in shaping the research findings (Sustrina, 2009).

4.2.2.2 Quantitative research

Quantitative research is an approach adopted for testing objective theories by analysing the relationship between variables. These variables can be measured so that numbered data can be analysed through statistical processes (Creswell, 2014). Quantitative research is mainly linked to a deductive approach, which focuses on using data to test a theory, taking measures to avoid bias, and being able to generalise and replicate the findings (Creswell, 2014; Saunders, Lewis and Thornhill, 2017). Nonetheless, it may also adopt an inductive approach (Saunders, Lewis and Thornhill, 2017).

4.2.2.3 Mixed method research

Mixed methods research is an approach to inquiry that integrates both qualitative and quantitative data. The concept of mixed methods research is that all the methods are biased and incomplete; therefore, the integration of quantitative and qualitative data compensates for the weaknesses of each type of data (Creswell, 2014). Mixed methods research may use different theory development approaches: inductive, deductive or abductive, which is a combination of both (Saunders, Lewis and Thornhill, 2017).

To conclude the study on research design, Table 4.2 presents a summary of the main aspects of the three major research designs: qualitative, quantitative and mixed methods.

Table 4.2 Qualitative, quantitative and mixed methods research

Sources: Creswell (2014) and Kumar (2019)

Aspects	Qualitative	Quantitative	Mixed Methods
Approach to inquiry	Unstructured, flexible and open methodology	Structure, rigid, pre-determined methodology	Can be unstructured, structured or both
Principal aim of the investigation	To describe variation in a phenomenon, situation, problem, etc.	To quantify the extent of variation in a phenomenon, situation, problem, etc.	To quantify and/or explore with multiple mixed methods a phenomenon to improve the accuracy or allow greater depth
Measurement of variables	Emphasis on the description of variables	Focus on some form of either measurement or classification of variables	Measurement and/or description
Sample size	Fewer cases	Emphasis on larger sample sizes	Larger sample size for some aspects and smaller for others, depending on the research objective
Main research topic	Includes multiple issues but gathers the	Explain predominance, incidence, scope, nature	Both or either, depending on the methods adopted

	information needed from fewer respondents	of issues, opinions and attitude; discovers regularities and build theory	
Strategies of inquiry	Phenomenology, grounded theory, ethnography, case study, and narrative	Surveys and experiments	Sequential, concurrent and transformative
Methods of inquiry	Open-ended questions, emerging approaches, text or image data	Close-ended questions, predetermined approaches, numeric data	Both open and closed-ended questions, both emerging and predetermined approaches and both quantitative and qualitative data and analysis
Researcher's role	• Positions him or herself • Collects participant meanings • Focuses on a single concept or phenomenon • Brings personal values to the study • Studies the context or setting of participants • Validates de accuracy of findings • Makes interpretations of the data • Develops an agenda for change or reform • Collaborates with participants	• Tests or verifies theories or explanations • Identifies variables to study • Relates variables in questions or hypotheses • Uses standards of validity and reliability • Observes and measures numerically • Uses unbiased methods • Employs statistical procedures	• Collects qualitative and quantitative data • Develops a rational for mixing • Integrates data at different stages of inquiry • Present visual pictures of the procedures of the study • Uses the practices of qualitative and quantitative research

4.2.2.4 The research design adopted

Due to the scarcity of data on BIM implementation in the Dominican Republic construction industry and the construction industry itself, a qualitative research design was adopted since it would provide the in-depth analysis needed to explore the research problem. As indicated by Creswell (2014), one of the reasons why a qualitative approach is carried out is that the subject of study has never been confronted with a specific sample or group of people, which is the case of the Dominican Republic. Qualitative research allows inductive development of theories and conceptual proposal on adoption, which is essential considering the novelty of BIM in the Dominican construction industry (Navendren *et al.*, 2014). Furthermore, one of the objectives of this research is to explore the challenges hindering the implementation of BIM in the Dominican construction industry (Refer to Chapter 1, Section 1.3). Navendren *et al.* (2014) suggested that the investigation of challenges to BIM implementation for a specific context requires the analysis of personal opinions, experiences and knowledge in that matter, for which a qualitative approach is appropriate. Lastly, in view of the pragmatic position of this study, the researcher considered necessary to get involved in the research process and collaborate with the participants (i.e. professionals of the Dominican construction industry and BIM Education stakeholders) to get a better insight of the Dominican construction industry and the status of BIM in the Dominican Republic.

The effectiveness of qualitative research in the field of BIM has been demonstrated with the work of Haron (2013) to study the organisational readiness of BIM in Malaysia; Bin Zakaria *et al.* (2013) to explore the adoption of BIM in Malaysia; Navendren *et al.* (2014) to investigate the challenges of BIM implementation in the UK; Lee, Wong and Tong (2014) to investigate barriers hindering BIM technology adoption in Hong Kong construction industry; Al Awad (2015) to explore the implementation of advanced IT and BIM by Jordanian construction SMEs; Al Naim (2018) to investigate the implementation of BIM in the Kingdom of Saudi Arabia (KSA); Chiew Teng, Tobi and Fathi (2018) to explore the benefits and barriers to BIM implementation from the perspective of Malaysian construction stakeholders; and Mohammad *et al.* (2018) to explore the challenges to BIM adoption for contractor's organisations in Malaysia.

Currently, there is limited literature available about BIM in the Dominican Republic and the construction industry itself; and the status of BIM is undocumented. This paucity of research in the context of the Dominican Republic suggested this qualitative study to be mainly exploratory (Naoum, 2012).

4.2.3 Research methods

Once the decision on the research design is made, the researcher needs to select the research methods to be adopted for their study which include the types of data collection, analysis and interpretation (Creswell, 2014). This section will cover the data collection and data analysis methods in qualitative research and the decision made in this regard for this study.

4.2.3.1 Data collection in qualitative research

Qualitative methods of data collection include interviews, focus groups, observations, textual data and audio-visual materials (Silverman, 2010; Robson and McCartan, 2016; Creswell and Poth, 2017). Research can inform their selection by looking into the most appropriate data collection strategies to answer the research questions of the study (Maxwell, 2012).

4.2.3.1.1 Data collection method adopted for this study

Interviews were the data collection technique selected for this study since they allow people to share their insight and understanding of a specific topic (Alshenqeeti, 2014). Interviews can be classified according to their structure and level of formality in structured, semi-structured and unstructured (in-depth) interviews. From these, semi-structured and unstructured interviews are usually known as qualitative research interviews (Saunders, Lewis and Thornhill, 2017). The main characteristics of each type of interview are presented in Table 4.3.

Table 4.3 Main characteristics of structured, semi-structured and unstructured interviews

Source: Patton (2002); Frankfort-Nachmias and Nachmias (2008); Myers (2013); Bryman (2016); Saunders, Lewis and Thornhill (2017)

Type of interview	Main characteristics
Structured	• Formal and standardised type of interview. • Use of predetermined questions in the form of questionnaires. • Requires thorough planning: Each question needs to be correctly and fully worded before the interview to make sure each interviewee is asked the same question. • The order of questions is strictly regulated. • Ensures consistency across interviews. • Role of the interviewer is minimum during the interview because there is no opportunity of improvisation. • Data analysis is facilitated since responses are easy to find and compare.
Semi-structured	• Use of a list of questions or specific topics to be covered (also known as interview guide/schedule). • The interview process is systematic and comprehensive by defining in advance the topics to be explored. • The interviewer does not have to stick to the pre-formulated questions. Questions may not be asked as they are written. • Provides some structure but allows improvisation since questions might emerge during the interview. • The interview process is flexible because participants are allowed to openly express their point of view of a topic that is presented to them. • There is some consistency across the interviews because of the use the pre-determined questions.
Unstructured interviews	• Informal type of interview, similar to a conversation. • Does not use a predetermined set of questions; therefore, the interviewer needs to be clear about the aspects to be explored during the interview. • Offers flexibility, spontaneity and responsiveness to participants differences and

	situational changes. • Interviewer introduces the topic briefly and allows interviewees to talk freely and say everything that they considered is relevant. • Appropriate to explore in-depth a general area. • There is no consistency across interviews. • It is susceptible to interviewer's influence (especially novice): biases and leading questions. • Data collected will be different from each person interviewed; therefore, data can be difficult to merge and analyse.

A semi-structured interviews approach was adopted in this study for several reasons. First, the flexibility of this type of interview allows the interviewees to express themselves freely; therefore, they are more likely, to be honest, and spontaneous in their responses. This way can be ensured that they are providing their own opinion, experience and knowledge, as sought in this study, and not being bias by the intervention of the interviewer. This flexibility also allows the emergence of topics that might not have been considered before, which may add more value to a study. Simultaneously, the use of an interview guide/schedule ensures that the conversation is flexible but still structured enough to explore the same topics of inquiry from each participant. Lastly, the consistency offered by this approach facilitates the organisation and subsequent analysis of the data.

4.2.3.1.2 Interviews preparation

This section describes the measures taken into consideration in the interview process stages: before, during and after the interviews.

4.2.3.1.2.1 Before the interview

This stage includes the ethics and location considerations of the interviews.

Ethics. The researcher must consider ethical aspects to protect the participants of the study. Once the research is designed, these aspects need to be presented to the proper ethics committee, where pertinent. An information letter to the participants of the study needs to be written, and they must be informed either orally or in writing about the research before their participation. The confidentiality of the participants must be assured, and they must be aware that their involvement in the study is voluntary and that they have the right to retire their data from the research at any time without risking their relationship with the researchers (Bengtsson, 2016). The researcher filled in an Ethics form explaining the data collection process, as required by the University of Wolverhampton, which was approved in December 2015.

Furthermore, the researcher included the following ethic aspects:

1. A cover letter was created to invite potential candidates to the study formally. Participants were given this letter for them to keep it as proof that they participated in the study. The letter included the following information:
    - Name of the research study (which changed in the last stages of the research journey).
    - Research team: the name of the researcher and the members and the supervisory team.
    - Background and aim of the research.
    - Implications of the participation: Approximate length of the interview, nature of the questions, and interviews' recording.

- Interviewee's rights: confidentiality, freedom of answering only what they feel comfortable with, give their details if interested in receiving information related to the research.

2. A consent letter that the researcher kept as proof that the interviewee kindly agreed to participate in the research noting its implications (Please, refer to Appendix 4-B).

Location. Usually, the location of the interviews was proposed by the interviewees. They generally took place in offices at working hours.

4.2.3.1.2.2 During the interview

Interviews were conducted through recording and note-taking methods.

Recording. Methods to record what the participants say are fundamental in interviews (Patton, 2002). In both phases of the study, the researcher recorded the interviews with the application "Smart recorder" for smartphones. The researcher would check the app and the volume of the smartphone before every interview to ensure they would be recorded successfully. After recording, the researcher would send the recording files via e-mail and save them in the cloud to avoid losing any data.

Note-taking. Along with recording, the researcher would carry the interview guide and a note pad to take essential and focused notes, since there was no need to worry about taking verbatim notes (Patton, 2002).

4.2.3.1.2.3 After the interviews

The interviews had to be transcribed to enable the data analysis process. The transcription process was carried out by the researcher, who listened to the interviews conducted in Spanish, and transcribed and translated them simultaneously into English. Transcripts were written in Microsoft Word and then inserted into the software NVivo, which was used to organise and manage the data collected for data analysis. The data analysis process carried out is discussed in detail in Section 4.3.3.

4.2.3.2 Data analysis for qualitative interviews

Grounded theory, thematic analysis, content analysis, Interpretative Phenomenological Analysis (IPA), and some forms of narrative analysis are well-known qualitative methods of analysis that generally use interviews as a data source (Robinson, 2014).

Content analysis was the data analysis method adopted to analyse the interviews in this study. In the following sections, the qualitative data analysis methods listed above are briefly explained, followed by a discussion as to why the method of content analysis was selected.

4.2.3.2.1 Grounded theory

Grounded theory method is part of a broader methodological approach, namely Grounded theory (Saunders, Lewis and Thornhill, 2017). The term grounded theory was introduced by Glaser and Strauss (1967) in their work "The Discovery of Grounded Theory". They defined it as *"the discovery of theory from data systematically obtained from social research"* whose method "*is a way of arriving at theory suited to its* *supposed uses"* rather than generating theory deductively from a priori assumptions. The Grounded theory method is based on two key concepts: "constant comparison" where data is collected and analysed at the same time, and "theoretical sampling" where decisions on which data should be subsequently gathered are defined by the theory that is being developed (Suddaby, 2006).

4.2.3.2.2 Thematic analysis

Thematic analysis is a qualitative method used to identify, analyse and report patterns (themes) in the data. It organises the data through data reduction and describes data sets in detail. The scope of this method usually goes further than this and allows the interpretation of various elements of the research topic (Braun and Clarke, 2006). Therefore, it is perceived as appropriate for any study that aims to get findings through interpretation (Alhojailan, 2012).

4.2.3.2.3 Content analysis

Content analysis can be defined as a systematic and objective way to describe and quantify phenomena. It enables the researcher to evaluate theoretical issues to improve understanding of the data and synthesise words into less content-related categories. Once data is classified into the same categories, it is expected that words and phrases share the same meaning (Elo and Kyngäs, 2008).

4.2.3.2.4 Interpretative Phenomenological Analysis (IPA)

The method of Interpretative phenomenological analysis (IPA) allows the detailed evaluation of personal lived experiences (Eatough and Smith, 2008). According to

Larkin, Watts and Clifton (2006), this type of analysis has two aims. The first one is trying to understand the individual's world and describe "what it is like". The second is to get a more openly interpretative analysis which intends to develop a critical and conceptual explanation of the individuals' personal 'sense-making' activities.

4.2.3.2.5 Narrative analysis

Narrative analysis consists of a compilation of analytical methods that aid to analyse different elements of a narrative. These methods can be combined depending on the aim of the research and nature of the data, but they must preserve the data's narrative form (Saunders, Lewis and Thornhill, 2017). The data is analysed to tell a story, a chronology of developing events, revelations or turning points (Creswell and Poth, 2017).

4.2.3.2.6 Data analysis method adopted for this study

For the selection of the qualitative method of analysis, the researcher discarded the approaches that were not suitable for the aim of this study. The Interpretative phenomenological analysis (IPA) was discarded because this study does not aim to analyse the personal experiences of its participants. Narrative analysis was disregarded because it is used to analyse narrative data, which is not the type of data required in this study.

The best approaches to be used for the analysis of the semi-structured interviews in this study were narrowed down into three: Grounded theory, Content analysis and Thematic analysis, the last two sharing various similarities. Among these three methods, grounded theory provides a complete framework to analyse qualitative data in detail. Nonetheless, the principal objective of grounded theory is to develop a theory, and the aim, research questions and objectives of this research do not have this purpose. Instead, they aim to identify, explore and report several aspects related to BIM in the Dominican construction industry. Besides this, the interviews were stacked during the interview process; therefore, it would have been impractical to do theoretical sampling and constant comparison, the two main characteristics of the Grounded Theory method.

Since grounded theory could not be adopted, this led to a debate between content analysis and thematic analysis. Both methods are usually adopted interchangeable. Also, there is confusion regarding their similarities and differences and how researchers should select them (Vaismoradi, Turunen and Bondas, 2013). Therefore, it was necessary to evaluate both methods very well before making a decision.

As explained in Section 4.2.3.2.2 and 4.2.3.2.3, thematic and content analysis organise and analyse the data systematically. Thematic analysis develops themes out of the data, while content analysis develops categories. They have different names but are the same concept of grouping the data that share the same meanings to answer the research questions and to attain data reduction. Furthermore, they can both adopt inductive or deductive approaches and are not tied to a specific research philosophy. Vaimoradi *et al.* (2013) further explained that both methods could answer the same set of research questions (e.g. *what reasons do people have for using or not using a service or procedure?*) and follow almost the same process of data analysis.

Regarding differences, Vaismoradi *et al.* (2013) emphasised that the main difference between both methods is that in content analysis data can be quantified by calculating the frequency of the categories, which can be used carefully as a representation of significance. On the other hand, thematic analysis enables an entirely qualitative, thorough and nuanced account of data.

Another critical difference is the manifest and latent content. In content analysis, the researcher needs to decide from the beginning whether to focus the analysis on the manifest or latent content of data (Graneheim and Lundman, 2004; Elo and Kyngäs, 2008; Vaismoradi *et al.*, 2013; Cho and Lee, 2014; Bengtsson, 2016). Conversely, thematic analysis includes both contents (Vaismoradi *et al.*, 2013). Manifest content comprehends the analysis of what the text says; considers the content aspect; describes the evident and apparent components; and is usually presented in categories (Graneheim and Lundman, 2004). The researcher commonly uses the participant's words and is conscious of the need to refer to the original text; therefore, it is likely to remain closer to the original meanings and contexts (Bengtsson, 2016). On the other hand, latent content refers to the analysis of what the text talks about; considers the relationship aspects; requires an interpretation of the underlying meaning of the text; and is usually presented in themes (Graneheim and Lundman, 2004). Elo and Kyngäs (2008) further explained that latent content intends to perceive aspects such as silence, laughter, sighs, posture, etc. In conclusion, the manifest context is close to the text; while the latent content is distant from the text yet close to the participant's lived experiences. Close to the text implies more objective description, whereas distant from the text represents more abstract descriptions and interpretations (Graneheim and Lundman, 2004).

Content analysis was the approach selected for this study mainly due to the content intended to be analysed. As per Robson and McCartan (2016), researchers make this selection based on the aim and research questions of the study. In this study, the aim and research questions required the analysis of manifest content. Moreover, the possibility of analysing the data qualitative and quantifying categories to determine the importance of the findings was considered a favourable approach that provides a more robust analysis in the research. Lastly, as Vaismoradi *et al.* (2013) indicated, content analysis would be more appropriate for the exploratory nature of this research by allowing the description of the issues that emerge from the data in a simple manner.

4.3 Research strategy

This section discusses the research strategy adopted in this study. In essence, the need for a preliminary study for the data collection, sampling and the data analysis process carried out in this research.

4.3.1 Need for a preliminary study

This research was carried out in two phases, namely the preliminary study and the main study. The researcher opted for a preliminary study to assure that the chosen research methods could meet the objectives of the research and train herself in conducting qualitative research. From the preliminary study, the researcher could identify what worked and did not entirely work for this study. The researcher could also refine the data collection techniques and identify other areas of study that were not considered initially. For that reason, both phases differ in some respect. In the preliminary study, semi-structured interviews were conducted following two interview guides, from which one was utterly discarded for the main study. In contrast, the other interview guide was kept and refined for the main study. Moreover, another interview guide was developed in the main study to explore an area that was not previously considered but emerged in the research process: BIM Education (Please refer to Figure 4.1). Research aspects of both phases are described in Sections 4.4 and 4.5.

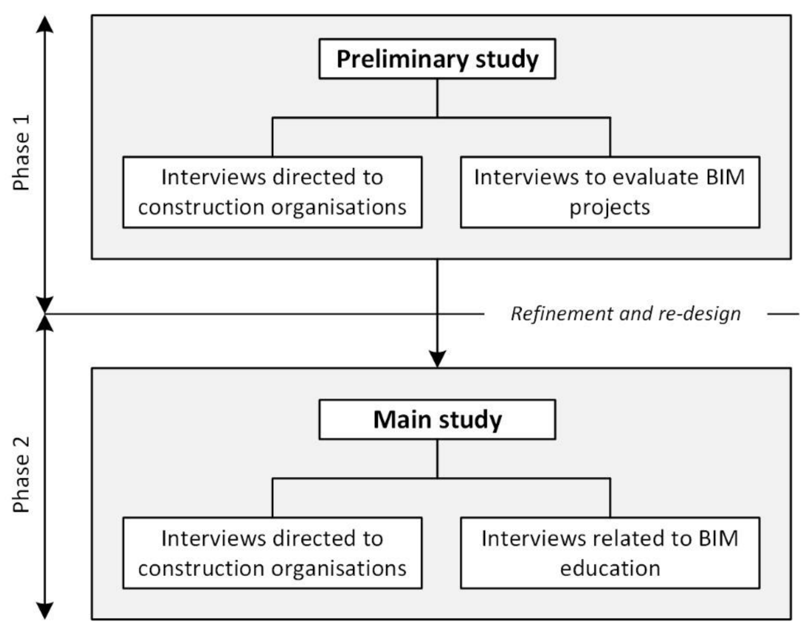


Figure 4.2 Phases of the research: preliminary study and main study

4.3.2 Sampling

Sampling is associated with the nature of the research. Sampling considerations in quantitative enquiry are related to probability sampling, while sampling considerations in qualitative inquiry are related to the concept of purposive sampling (Bryman, 2016). The reasoning and strength of probability sampling come from the aim of generalising data; while in purposive sampling come from the importance of in-depth understanding (Patton, 2002).

Qualitative research generally deals with small samples which are studied in depth within their context and selected purposively (Miles *et al.*, 1994; Patton, 2002). Purposive sampling aims to select information-rich cases strategically; thus, those sampled are appropriate to the research questions that have been formulated (Bryman, 2016). Purposive sampling was adopted in the selection of the interviewees due to its appropriateness for in-depth qualitative research.

4.3.2.1 Sample universe

When adopting purposive sampling, the research needs to know very well the criteria to include or exclude potential participants (Bryman, 2016). This inclusion and exclusion criteria define the sample universe of a study, also known as "study population" or "target population". Sample universe refers to the sum of people from which cases may be sampled in a study (Robinson, 2014).

As previously explained, this study was conducted in two phases which differ in some respects. Therefore, the sample universe cannot be seen as a whole, but as part of each phase. The sample universe in the preliminary and main study are described below.

4.3.2.1.1 Sample universe in the preliminary study

The sample universe established in the preliminary study was twofold: professionals of the construction industry belonging to construction organisations in the Dominican Republic and construction projects in the Dominican Republic where BIM has been implemented. This sample universe was defined to achieve the third objective of this study (i.e. To critically appraise and document the BIM awareness and implementation in the Dominican construction industry).

The inclusion criteria to select the professionals were that they must be a permanent staff of construction organisations and have extensive knowledge of how the organisation works and develops their projects. In terms of the construction organisations, the criteria included primarily to have developed at least one construction project. They did not necessarily have to implement BIM because as it was expected not to find many organisations that implement BIM due to the undocumented state of BIM in the country. If organisations did not implement BIM, they would still offer valuable insight related to their current status. General information regarding these organisations is presented in Appendix 4-F. Regarding construction projects, the criteria included being a BIM project developed by a Dominican construction organisation in the Dominican Republic.

4.3.2.1.2 Sample universe in the main study

Similar to the preliminary study, the sample universe of the main study was twofold. Only one sample universe defined in the preliminary study continued to be part in the main study (i.e. the professionals of the construction industry belonging to construction organisations) following the same inclusion criteria. On the other hand, BIM Education/training stakeholders was the sample universe considered to fulfil the fourth objective of this study (i.e. To explore and document the presence of BIM Education in the country). The inclusion criteria of the latter consisted of professionals of the construction industry related to the delivery of any mode of education/training strictly associated with BIM in the country.

4.3.2.2 Sampling strategy

There are multiple purposive sampling strategies, from which snowball sampling was the strategy used to sample participants in both, the preliminary and main study. Snowball sampling is a purposive sampling strategy in which the researcher samples a small group of people who can contribute to the research questions. These sampled participants suggest other participants who meet the criteria to be part of the research, the recommended participants, in turn, suggest other participants, and so forth (Bryman, 2016). Snowball sampling is mainly implemented to get information-rich participants (Patton, 2012) and to get respondents where there are not many potential candidates or where some degree of trust is necessary to start contact (Atkinson and Flint, 2001).

In the Dominican Republic, there are no public databases of the construction industry where the researcher could initiate contact with potential candidates for this research. For that reason, the professional background of the researcher was used as a starting point to sample the first participants of this study, and the snowball sampling strategy was adopted to grow this sample. The researcher studied Architecture in the Dominican Republic and worked for three years in the field. Therefore, she had extensive networking of not only Architects but other professionals of the construction industry. The initial group of participants was directly sampled through the researcher's networking via phone and e-mail. She would first have a brief conversation about the study with the potential participants and explain them the criteria to be part of the research. If they met the requirements and agreed to participate, a formal invitation would be sent to their e-mails (Refer to Section 4.2.3.1.2.1 and Appendix 4-A). The researcher would ask for the referral of potential participants either in the first contact or during the interviews. To make sure that suggested participants would meet the criteria, the researcher would request some details about their profile. If they did not meet the criteria, she would inform it to the interviewees, and the recommendation would be instantly discarded.

In the main study, the participants were sampled from the researcher's network and through an online search for potential participants in *Google*, the professional networking platform *LinkedIn* and the social media platform *Facebook*. This online search strategy was adopted due to the limited number of people within the field of BIM education in the D.R. and the researcher's network. Different keywords in Spanish were used for this purpose: *BIM + Republica + Dominicana; BIM + RD; BIM + Educacion + Republica + Dominicana; BIM + Diplomado + Republica + Dominicana; BIM + Cursos + Republica + Dominicana; BIM + Universidad + Republica + Dominicana; BIM + Formacion + Republica + Dominicana*. A few professionals were found, their profiles were analysed to see if they met the criteria, and they were contacted via message. If agreeing to participate, a formal invitation would then be sent via e-mail. Only two participants were sampled from this online search, both for the interviews related to BIM Education (Refer to Chapter 6, Section 6.2).

Through snowball sampling, a total of 17 professionals from 12 construction organisations participated in the preliminary study. On the other hand, through snowball sampling and the online search explained above, a total of 42 professionals from 25 organisations and related to BIM Education participated in the main study. It is important to note that a construction organisation (Org. 12) participated in the preliminary study in the interview aiming to evaluate BIM projects and in the main study in the interviews directed to construction organisations.

4.3.2.3 Sample size

The sample size of this research was determined by data saturation, approach in which the researcher stops gathering data when new data does not foment new perspectives or does not present new characteristics (Charmaz, 2006). Semi-structured interviews were the data collection strategy adopted for this research. In total, 48 interviews were conducted in this study (Refer to Table 4.4). The researcher reached data saturation in the 36th interview for construction organisations (interview no. 25 in the main study) and in the 7th interview related to BIM Education. However, because prior arrangements had been made with the interviewees, the researcher proceeded to conduct the 26th, 27th and 28th interview directed to construction organisations and the 8th interview related to BIM Education in the country. This sample size also falls within what is acceptable in qualitative research (Creswell, 2017; Saunders, Lewis and Thornhill, 2017).

Table 4.4 Total of interviews conducted in this study

Interviews conducted in this study	
Preliminary study	• Construction organisations: 11 • BIM project: 1
Main study	• Construction organisations: 28 • BIM Education: 8
Total	48

4.3.3 Data analysis process

As presented in Section 4.2.3.2.6, content analysis was the data analysis approach selected for this study. There are three methodological approaches to content analysis: inductive, deductive and abductive (Graneheim *et al.*, 2017). The inductive approach in content analysis is also known as "conventional content analysis" (Hsieh and Shannon, 2005), "data-driven" or "text-driven" (Graneheim *et al.* 2017). This approach is suggested when there is not sufficient previous knowledge about the phenomenon or when this knowledge is incomplete (Elo and Kyngäs, 2008). Researchers evade the use of predetermined categories and enable the categories and names of the categories to emerge from the data (Hsieh and Shannon, 2005). On the other hand, deductive content analysis, also known as "*directed content analysis"* (Hsieh and Shannon, 2005) and *"concept-driven"* (Graneheim *et al.* 2017), is adopted when the study aims to either test existing theory or retest existing data in a new context (Cho and Lee, 2014). The deductive content analysis begins with predetermined codes and categories that come from earlier significant theory, research or literature (Cho and Lee, 2014). Lastly, abductive content analysis, also known by the name *"complementary"* (Blackstone, 2012), "combined" (Elo and Kyngas, 2008), "*fuzzy logic"* (Rolfe, 1997) or *"retroductive"* (Sayer, 1992), is a combination of inductive and deductive content analysis. This approach can be adopted for a complete understanding of the topic, and it requires to move back and forth between deductive and inductive approaches (Graneheim *et al.* 2017).

The findings reported in this research are based on an inductive content analysis approach. The researcher first opted an abductive approach in the preliminary study, but findings from this phase suggested an inductive approach would be more appropriate for the whole study. Details on the abductive approach in the preliminary study are discussed in Section 4.4.4. The next section will review the data analysis process of the inductive content analysis approach of this research.

4.3.3.1 Process of inductive content analysis

The process of inductive content analysis adopted in this research is primarily informed by Hsieh and Shannon (2005), Elo and Kyngäs (2008) and Cho and Lee (2014). It consists of four phases: preparation, coding, abstraction and reporting phase. The next sections will explain how each phase developed and how the software NVivo was used for the data analysis.

4.3.3.1.1 Preparation phase

The preparation phase consisted of preparing all the transcribed data collected from the semi-structured interviews into the software NVivo. For that, the Microsoft Word documents were imported into the software and saved as *Internal sources*. Transcripts were organised into folders as per the phase the interviews were conducted. For the preliminary study, two Internal folders were created: "Interviews to construction organisations" and "BIM project". For the main study, another two folders were created: "Interviews to construction organisations" and "BIM Education". Folders were numbered to control their order in the list (Refer to Figure 4.3).

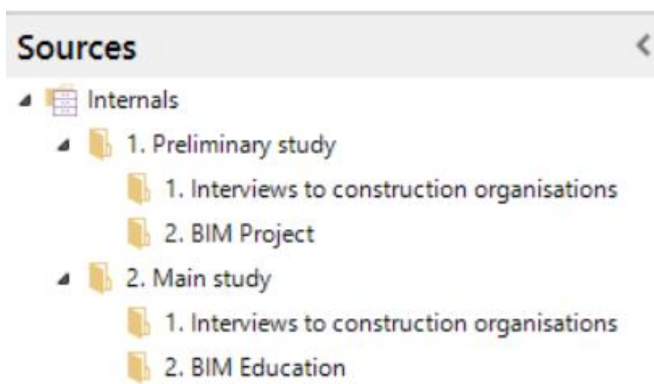


Figure 4.3 Organisation of interviews transcripts in NVivo

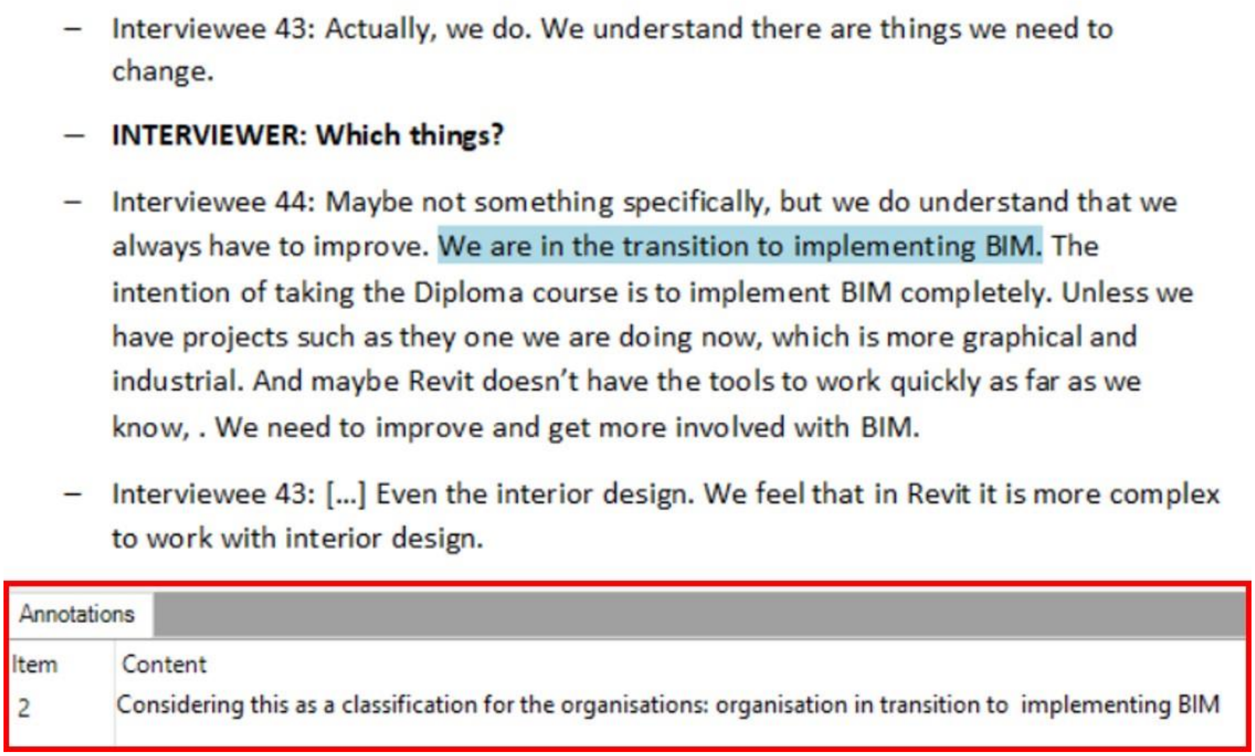
4.3.3.1.2 Coding phase

The coding phase includes two processes: open coding and categorisation.

4.3.3.1.2.1 Open coding

Open coding is a stage that content analysis (and thematic analysis) share with Grounded Theory (Vaismoradi *et al.* 2013; Cho and Lee, 2014). Corbin and Strauss (1990) defined it as the interpretive process where data is categorised analytically with codes. Through open coding, events/actions/interactions are compared to identify either similitudes or disparities. They are also assigned conceptual labels so they can be later grouped into categories and sub-categories.

The open coding process started when the interviews were carried out. As suggested by Elo and Kyngäs (2008), the researcher would write notes on the interview guide when important topics emerge from the interviewees' responses. These notes were transferred to the software NVivo with the tool *Annotation* (Refer to Figure 4.4). A few categories freely emerged with this process (Elo and Kyngäs, 2008). The researcher continued creating more notes while reading the transcripts in NVivo to aid the open coding process. The rest of the codes were generated by reading the text repeatedly. Strauss and Corbin (1990) recommended a detailed analysis line-by-line, sentence-by-sentence or paragraph-by-paragraph analysis to create initial categories at the beginning of a study. Most of the initial coding done in this research mainly followed the sentence-by-sentence and paragraph-by-paragraph approach.



- Interviewee 43: Actually, we do. We understand there are things we need to change.
- **INTERVIEWER: Which things?**
- Interviewee 44: Maybe not something specifically, but we do understand that we always have to improve. We are in the transition to implementing BIM. The intention of taking the Diploma course is to implement BIM completely. Unless we have projects such as they one we are doing now, which is more graphical and industrial. And maybe Revit doesn't have the tools to work quickly as far as we know, . We need to improve and get more involved with BIM.
- Interviewee 43: [...] Even the interior design. We feel that in Revit it is more complex to work with interior design.

Annotations

Item	Content
2	Considering this as a classification for the organisations: organisation in transition to implementing BIM

Figure 4.4 Note-taking in NVivo with the tool *Annotation*

Coding in NVivo is stored in *nodes* (Bazeley and Jackson, 2013), in which the text as presented as reference links with the exact location of the text. The nodes are listed systematically as soon as they are created, which keeps the data organised. Nonetheless, since this study had two different phases with disparate content from the interviews, it was necessary to organise the nodes in folders. Three folders were created throughout the whole data analysis: Preliminary study, Main study and Shared analysis (Refer to Figure 4.5). The first two folders stored the nodes that emerged from the interviews conducted at each phase of the study. The third folder was created afterwards because of the need of gathering the nodes containing specific topics that were covered in the interviews to construction organisations conducted in both phases of the study (e.g., reasons why BIM is not implemented) (Refer to Chapter 5, Section 5.4.1).

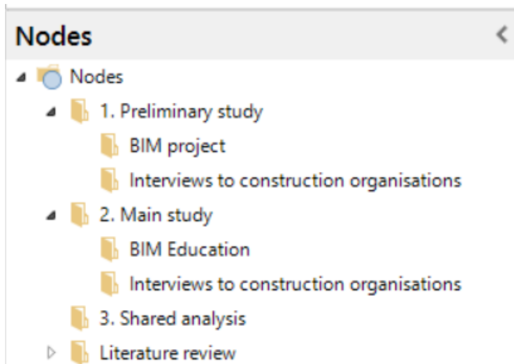


Figure 4.5 Organisation of nodes in NVivo

4.3.3.1.2.2 Categorisation

After open coding, it is necessary to group the preliminary codes into categories. Categories are created to describe the phenomenon, improve understanding and develop knowledge. Through interpretation, the researcher decides which data will be placed under the same category (Elo and Kyngäs, 2008). The researcher started to create categories by grouping the preliminary codes with similar aspects or meanings. Sub-categories were created when smaller concepts had to be included in a category. When much smaller concepts were detected, sub-subcategories were incorporated into the sub-categories. NVivo facilitated the categorisation process with the "branching tree system", in which nodes are easily structured in categories, subcategories and sub-subcategories (Bazeley and Jackson, 2013).

An essential aspect of creating categories in content analysis is that data cannot fall between two categories or be located in more than one category (Cho and Lee, 2014).

The researcher would check the nodes of the interviews after they were coded to prevent this. The nodes were checked with two features located in the View Tab of NVivo: *Highlight* and *Coding Stripes*. With the Highlight feature and the option *Coding for all nodes*, all the nodes contained within each interview would be highlighted. Then, the Coding stripes would be activated by selecting the option *All nodes coding*. As presented in Figure 4.6, the Highlight feature allowed the researcher to see the coded text within each interview (1). The coding stripes, which are aligned to the text on the right-hand side of the screen, allowed the researcher to quickly check to which nodes the coded text belongs to (2). By scrolling the coding stripes on the right (3) the researcher could detect if the nodes overlapped or not. If they did, it meant that the same data was coded twice, and the researcher had to un-code the unrepeated data set from the node that was less relevant for the analysis. This process was fundamental during the data analysis process because the researcher was sure that the data emerged from the interviews was not used more than once for the analysis of different topics.

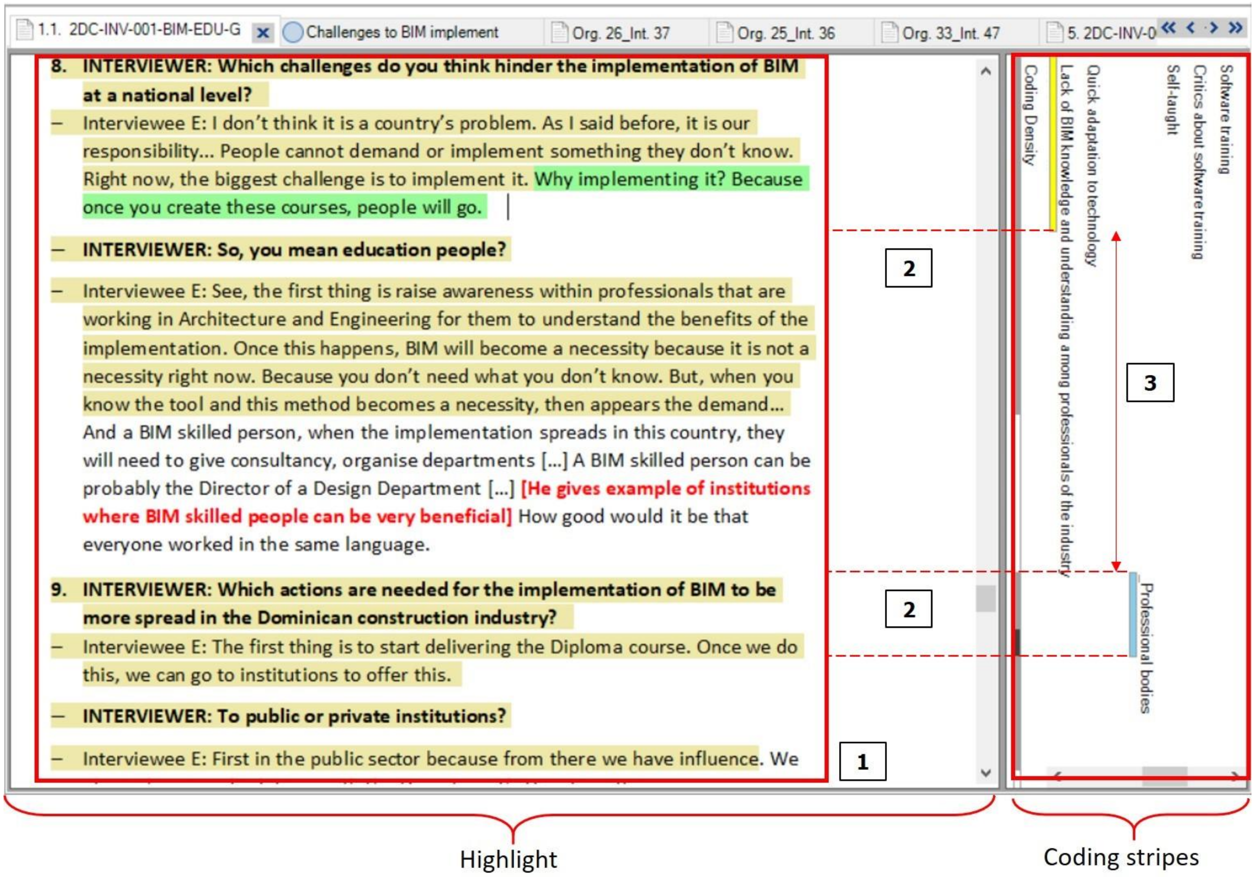


Figure 4.6 Use of Highlight and Coding Stripes in NVivo to check categories

Furthermore, when some of the "free" categories seemed irrelevant in the categorisation process, the researcher would place them in a node named "Miscellaneous". This node was checked repetitively throughout the whole analysis process to ensure that no data that would contribute to the research were excluded from the analysis.

4.3.3.1.3 Abstraction phase

The process of abstraction consists of developing a general explanation of the research topic through categories. Each category is named with content-characteristics words (Elo and Kyngäs, 2018).

For this stage, the researcher started to analyse the created categories by making comparisons among them (Corbin and Strauss, 1990). The researcher would examine the content within each category and sub-categories in to check if all the coded text should belong to them. During this process could be detected when some excerpts did not belong to a given category and should, instead, be placed in another category or if a new category should be created for them. Some categories with specific content had to be included in larger categories with a much broader meaning. Also, some categories were compared with others and merged if they shared similarities. This process can make significant changes to the initial categories and requires re-categorising and re-organising the data repetitively. This process was facilitated thanks to the branching tree system offered by the software NVivo. Besides this, the researcher also developed tree diagrams by hand as advised by Hsieh and Shannon (2005) to examine the categories and subcategories of certain topics that were too broad and required a thorough analysis (See Figure 4.7).

After the analysis of all the main categories created, the researcher would develop definitions for each of them to understand their rationale. For that, the researcher would provide a general description of each category in the *Nodes properties* in NVivo (Refer to Figure 4.8).

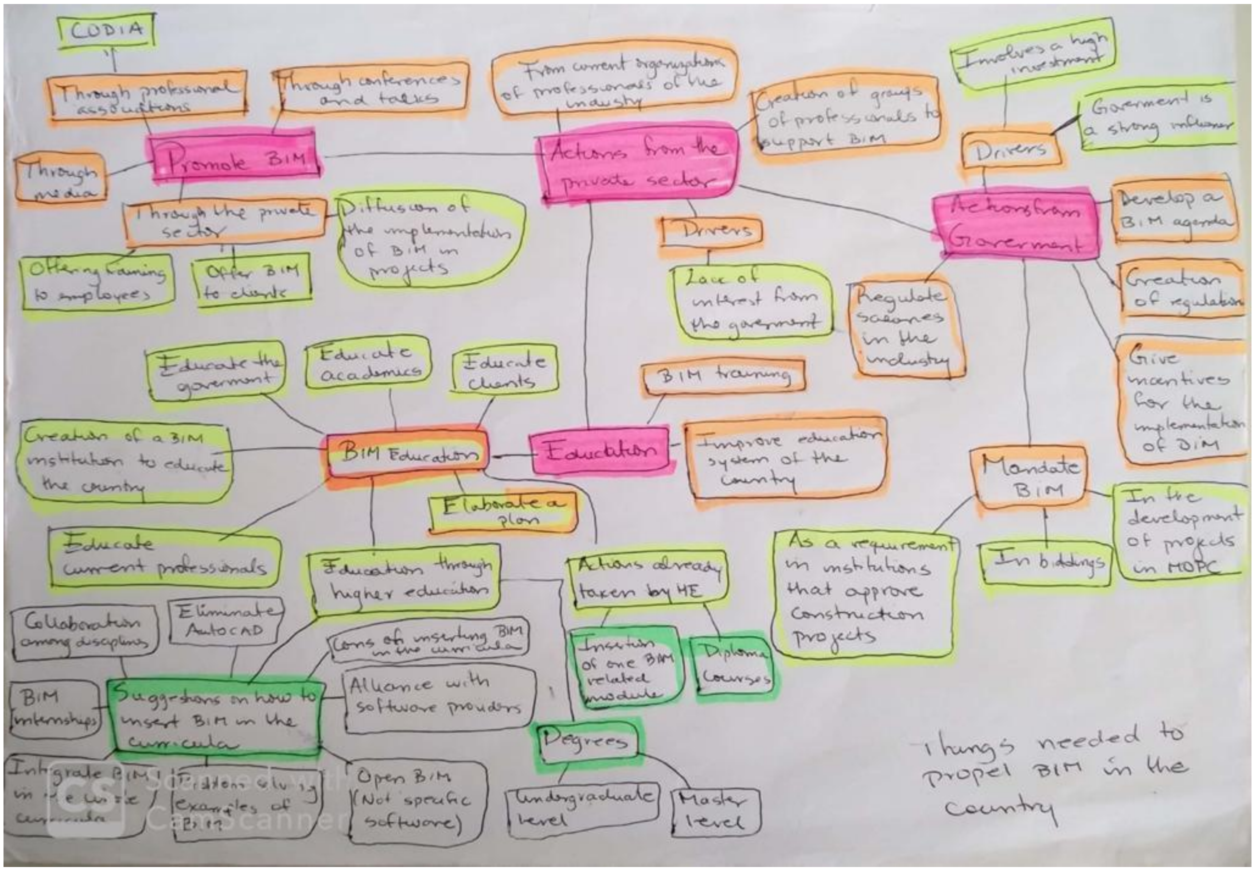


Figure 4.7 Tree diagrams created by hand in the abstraction process of content analysis

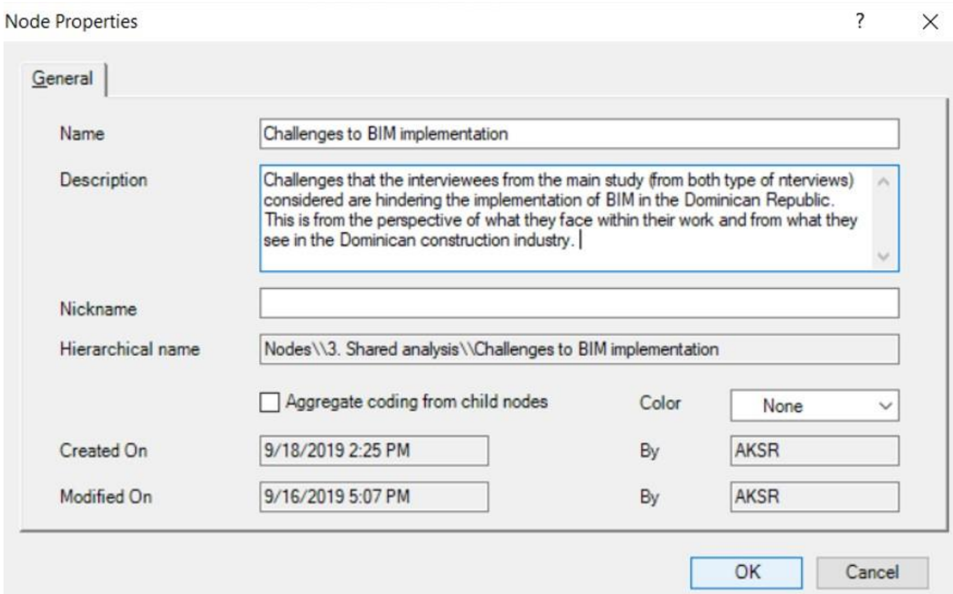


Figure 4.8 Example of the definition of main categories in the software NVivo

The abstraction process in content analysis lasts until necessary (Elo and Kyngäs, 2008). Categories and subcategories continued evolving throughout the study. Figure 4.9 presents the last categories, sub-categories and sub-subcategories created in NVivo to study the challenges hindering the implementation of BIM in the Dominican construction industry, which are discussed in Chapter 7.

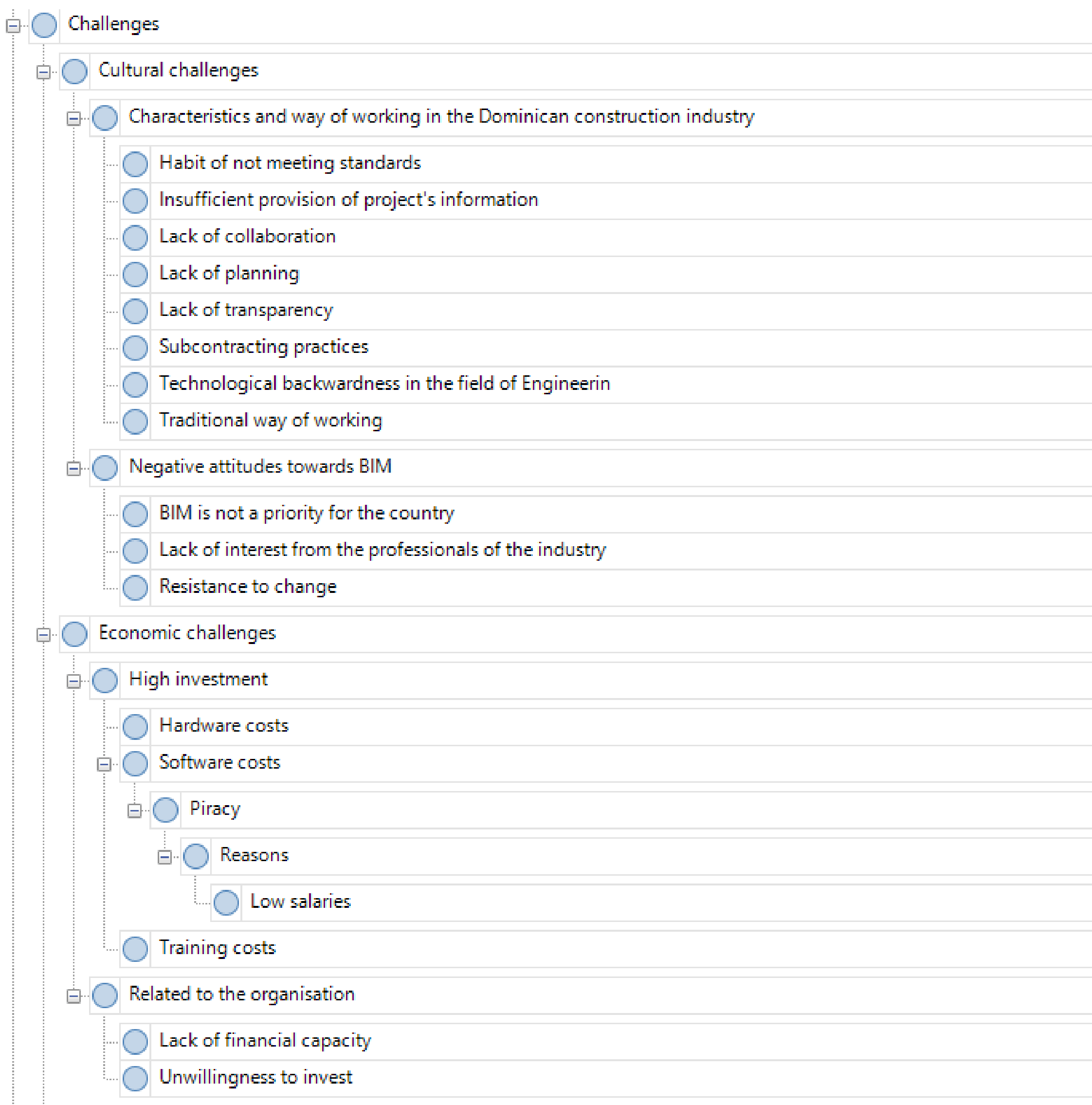
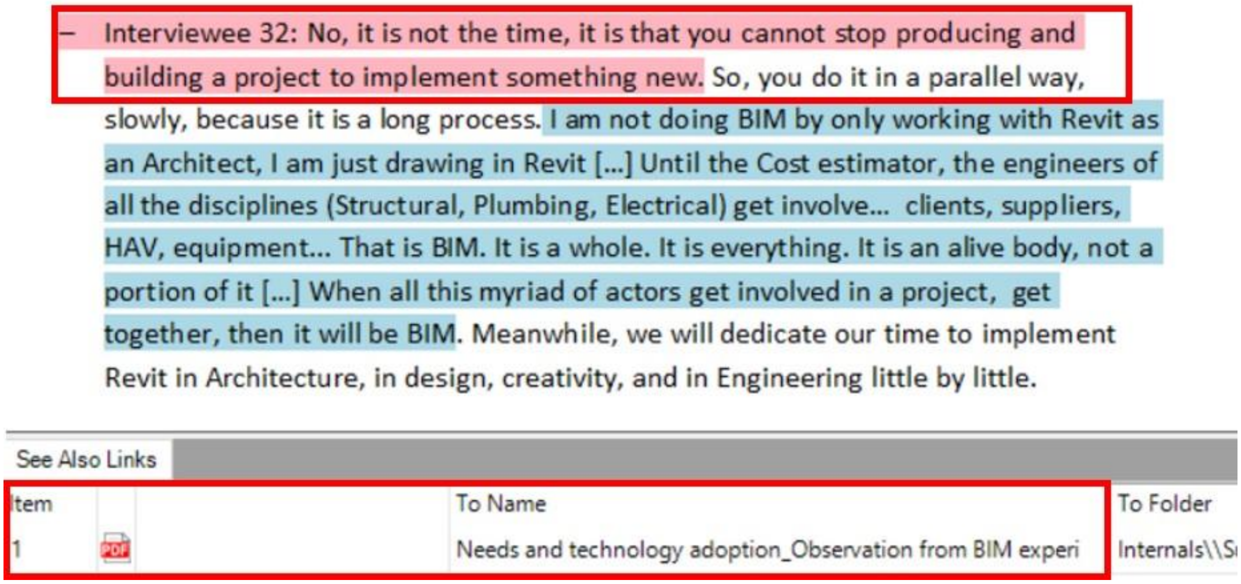


Figure 4.9 Last branching tree system created in NVivo to study the challenges hindering the implementation of BIM in the Dominican construction industry

4.3.3.1.4 Reporting phase

The analysis process and results need to be described thoroughly. Thus, readers can get a good understanding of how the analysis was executed and its strengths and constraints. Results are reported explaining the content of the categories, which are described through their subcategories, and so forth (Elo and Kyngäs, 2008). Chapter 5, 6, and 7 contain the findings from the content analysis carried out in this study.

For the writing-up process, Bengtsson (2016) advised that the researchers must think about how the new findings correlate to the literature to assess whether the result is reasonable or logical to make appropriate inferences. Following this suggestion, the researcher supported the content of the categories and subcategories with literature in the writing-up process. For that, the relevant literature on the BIM topics covered for this study was stored into the NVivo file as internal sources. While reading the literature, if certain concepts covered in the data analysis would appear in the text, the researcher would check the nodes containing these categories and copy and link the excerpts of both, the interview transcript and the literature file, with the NVivo tool *Paste as See also Link*. Figure 4.10 shows how the literature file is linked to the excerpt from the interview transcript, and Figure 4.11 shows how the excerpt from the literature file is linked to the interview transcript.

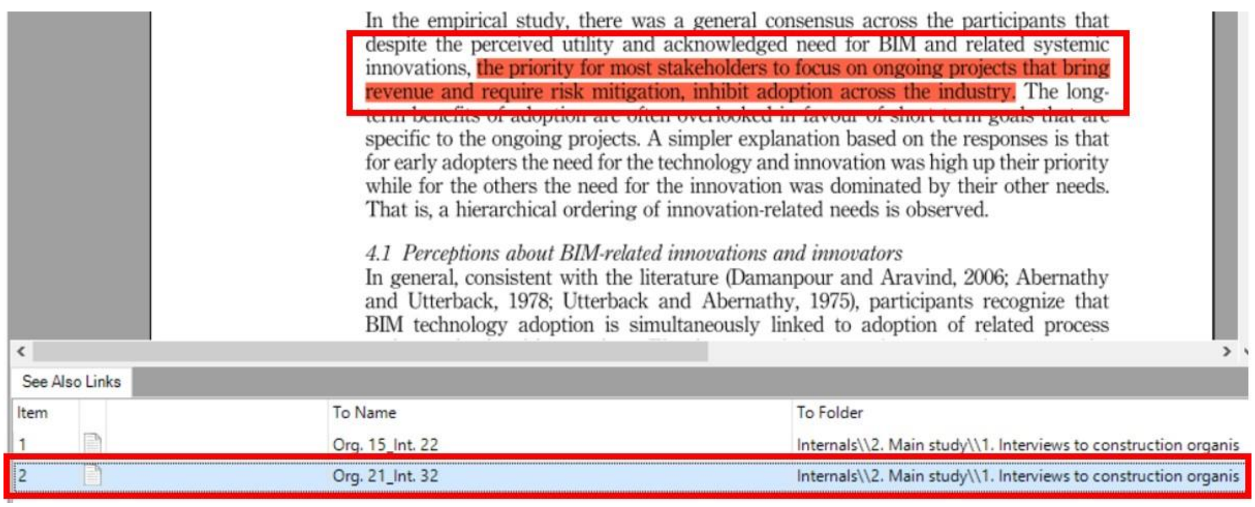


– Interviewee 32: No, it is not the time, it is that you cannot stop producing and building a project to implement something new. So, you do it in a parallel way, slowly, because it is a long process. I am not doing BIM by only working with Revit as an Architect, I am just drawing in Revit [...] Until the Cost estimator, the engineers of all the disciplines (Structural, Plumbing, Electrical) get involve... clients, suppliers, HAV, equipment... That is BIM. It is a whole. It is everything. It is an alive body, not a portion of it [...] When all this myriad of actors get involved in a project, get together, then it will be BIM. Meanwhile, we will dedicate our time to implement Revit in Architecture, in design, creativity, and in Engineering little by little.

See Also Links

Item		To Name	To Folder
1	PDF	Needs and technology adoption_Observation from BIM experi	Internals\\S

Figure 4.10 Excerpt of interview linked to the literature



In the empirical study, there was a general consensus across the participants that despite the perceived utility and acknowledged need for BIM and related systemic innovations, the priority for most stakeholders to focus on ongoing projects that bring revenue and require risk mitigation, inhibit adoption across the industry. The long-term benefits of adoption are often overlooked in favour of short-term goals that are specific to the ongoing projects. A simpler explanation based on the responses is that for early adopters the need for the technology and innovation was high up their priority while for the others the need for the innovation was dominated by their other needs. That is, a hierarchical ordering of innovation-related needs is observed.

4.1 Perceptions about BIM-related innovations and innovators
In general, consistent with the literature (Damanpour and Aravind, 2006; Abernathy and Utterback, 1978; Utterback and Abernathy, 1975), participants recognize that BIM technology adoption is simultaneously linked to adoption of related process

See Also Links

Item		To Name	To Folder
1		Org. 15_Int. 22	Internals\\2. Main study\\1. Interviews to construction organis
2		Org. 21_Int. 32	Internals\\2. Main study\\1. Interviews to construction organis

Figure 4.11 Excerpt of the literature linked to the interview

Lastly, categories and subcategories were also presented graphically through diagrams to summarise a topic and enable easy identification of the categories' hierarchy (Refer to Figure 4.12).

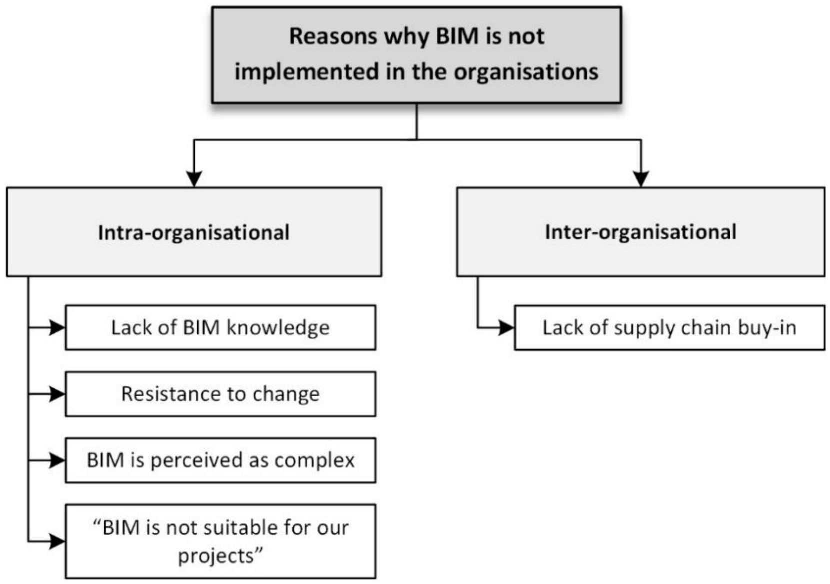


Figure 4.12 Diagram containing the categories and subcategories to explain the reasons why BIM is not implemented in the participant organisations that do not implement BIM (Chapter 5, Section 5.4.1.1)

The whole data analysis process adopted in this study, which followed the inductive content analysis approach and was assisted by the software NVivo, is summarised in Figure 4.13.

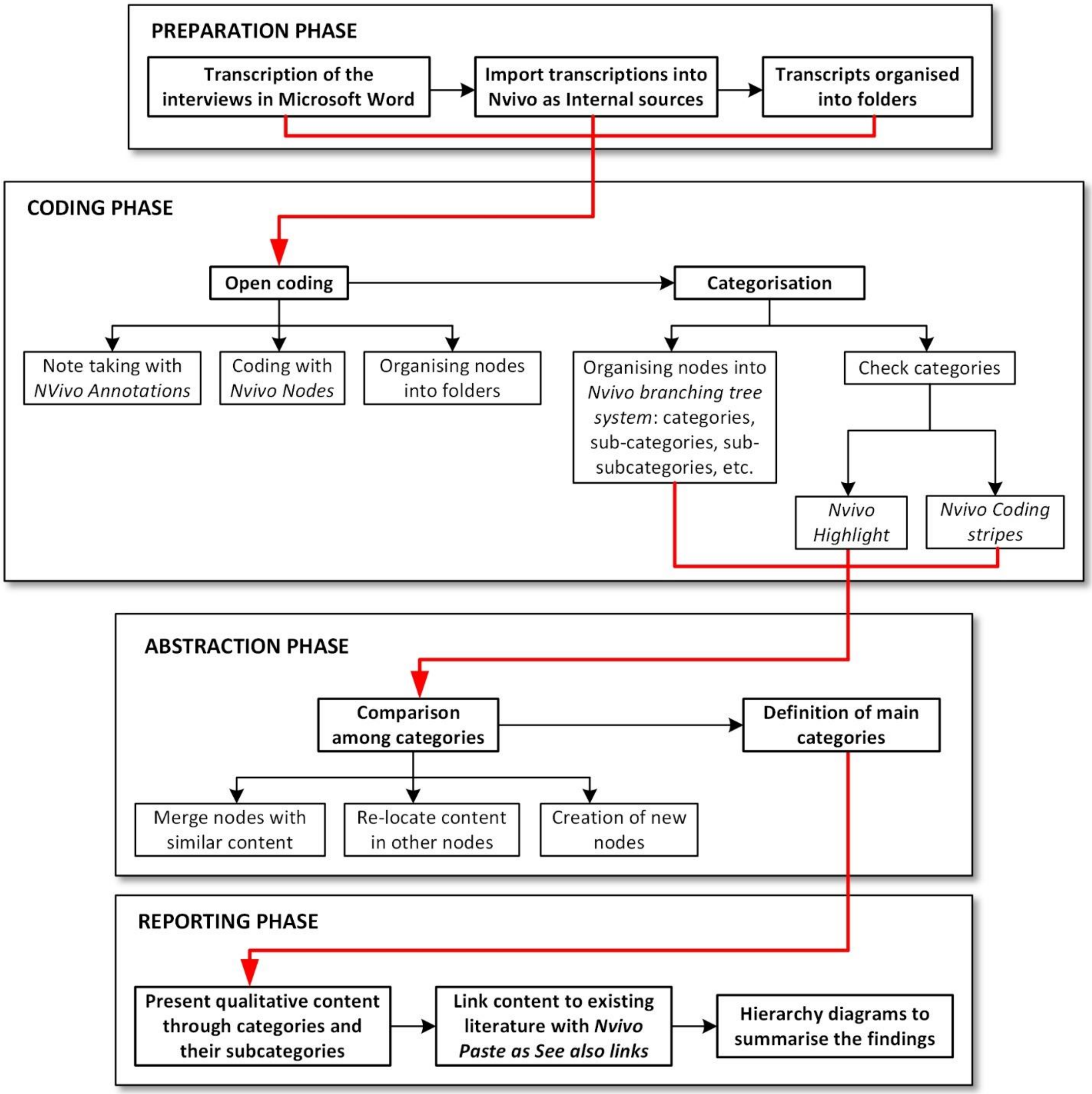


Figure 4.13 Inductive content analysis process of this study assisted by the software NVivo

4.3.3.2 Trustworthiness in content analysis

The research process and findings should be conferred upon concepts linked to trustworthiness. There is no consensus as to how to judge the trustworthiness of qualitative research. Some scientists defend the use of the same criteria and concepts for quantitative research, namely validity, reliability and generalisability. On the contrary, others affirm that different principles and concepts are needed. For instance, the concepts of credibility, dependability, transferability and confirmability developed by Lincoln and Guba (Bengtsson, 2016). The last criteria have been adopted to ensure the trustworthiness of the content analysis process followed in this study.

4.3.3.2.1 Credibility

Credibility refers to the study process undertaken to define how the data and the analysis have been executed and to guarantee that relevant data has not been omitted (Bengtsson, 2016). Credibility can be validated through several strategies. In this research, triangulation, peer review or debriefing, and member checking were adopted.

4.3.3.2.1.1 Triangulation

Triangulation encompasses the use of more than one source of data and data collection methods to confirm the credibility, validity and authenticity of research data as well as its analysis and interpretation (Saunders, Lewis and Thornhill, 2017). In this study, relevant literature was used to confirm and support findings found from the data collected. In some instances, data obtained from an organisation was triangulated through inquiring more than one employee.

4.3.3.2.1.2 Peer review or debriefing

Peer review or debriefing affords an external check of the research process (Creswell and Poth, 2017). Lincoln and Guba (2006) argued that a peer debriefer act as a "devil's advocate" who keeps the researcher honest; ask difficult questions about methodology, meanings, and interpretations. The researcher performed peer debriefing mainly through research activities hosted by the university, and the presentation of conference papers (Refer to Chapter 9, Section 9.5). It is worth mentioning that this research was highly peer-reviewed by researchers and staff through three expositions in the Built Environment & Engineering Research Seminar (BEERS) hosted by the University of Wolverhampton in 2016, 2017, and 2018 respectively. The supervisory team (compound by three experienced researchers) contributed to this strategy as well in their supervisory role.

4.3.3.2.1.3 Member checking

In member checking, the researcher goes back to the participants to get their opinion on the credibility of the findings and their interpretation (Creswell and Poth, 2017; Saunders, Lewis and Thornhill, 2017). This strategy was adopted for the validation of the framework of this study. Details of this process are presented in Chapter 8 (Section 8.5).

4.3.3.2.2 Dependability

Dependability, reliability or auditability refers to whether the process of the research is congruent and reasonably stable over time and across researchers and methodologies (Miles *et al.*, 1994). As suggested by Bengtsson (2016), to ensure dependability, the researcher kept track of coding decisions and used memos to track any changes because data has to be re-coded several times during the data analysis process. Aided by the software NVivo, memos were linked to the coded data. Thus the researcher could see previous and latest coding. The decision of the last codes used for the data analysis was highly influenced by supporting literature to avoid bias.

Graneheim *et al.* (2017) recommended the inclusion of more than one researcher in the data analysis process since the researcher's interpretations can vary, and a co-researcher can have different interpretations. This analysis is usually defined as a consensus. To carry out this strategy, the researcher asked a PhD colleague also following the method of content analysis on her research, to code the same interview excerpt to make comparisons between both codings. This exercise proved the reliability of the analysis as both codings were consistent (Refer to Appendix 4-G).

4.3.3.2.3 Transferability

Transferability, external validity, fittingness or generalisability (Guba, 1981; Miles *et al.*, 1994) refers to the extent in which the results may transfer to other settings, groups or a different number of participants or study elements (Bengtsson, 2016). As per Bitsch (2005, p. 1985), the *"researcher facilitates the transferability judgment by a potential user through 'thick description' and purposeful sampling".* In other words, the researcher enables transferability when the research is explained in detail, and the participants are chosen purposively (Anney, 2014). Qualitative studies usually make limited declarations on transferability because their focus is primarily on smaller samples, and even single cases (Patton, 2002; Bengstsson, 2016). That can also be attributed to the fact that phenomena are strictly related to the times and the context in which they are studied (Guba, 1981).

This study makes no claims that findings in other contexts will be similar to this study because qualitative data is context-specific. Nonetheless, since the readers decide to determine the transferability of a study to different settings, the researcher has provided a thorough description of the research process carried out, including the data collection process, the context of the inquiry and how data has been analysed and reported. Also, participants have been selected purposively as per the objectives of the study and have been described accordingly.

4.3.3.2.4 Confirmability

Confirmability is mostly a matter of data presentation and refers to the neutrality and objectivity of the data (Bengtsson, 2016). Graneheim and Lundman (2004) suggested recognising participants' contribution to the findings to ensure confirmability. In this research, participants input is presented by indicating the participant and describing the content of their statement. Quotes are also used to emphasise important comments from the participants of the study.

4.4 Preliminary study

This section aims to describe unique aspects of the preliminary study by providing relevant information regarding its objectives, specific details related to the data collection, interviews design, and data analysis approach. Furthermore, it discusses the impact of the preliminary study on the main study.

4.4.1 Objectives

When the preliminary study was carried out, the initial objectives of this study were:

- To critically analyse the concept of Building Information Modelling (BIM) and emerging technologies related to its implementation.
- To investigate BIM global implementation initiatives to identify the critical enabling factors for country-wide BIM implementation.
- To critically appraise and document the BIM awareness and implementation in the Dominican construction industry.
- To identify and document the challenges hindering the implementation of BIM in the Dominican construction industry.
- To develop and validate a toolkit to facilitate the implementation of BIM in the Dominican construction industry.

The evolution of these objectives is further discussed in Sections 4.4.5 and 4.5.3.

4.4.2 Data collection details

4.4.2.1 Timeline

This study was conducted from the 4^{th} of January to the 16^{th} of January 2016.

4.4.2.2 Participants characteristics

The profile of the interviewees that participated in the preliminary study is presented in Table 4.5.

Table 4.5 Profile of the interviewees that participated in the preliminary study the interviews directed to construction organisations

Interviewee	**Profession**	**Role in the organisation**	**Org.**
Interviews to construction organisations			
1	Architect	Architect designer	1
2	Architect	President of the company	2
3	Electronic and Communication Engineer	Project manager	
4	Civil Engineer	Cost analyst	3
5	Architect	Senior Architect	3
6	Architect	Owner	4
7	Architect	CEO	5
8	Architect	Architect	5
9	Architect	Architect	5
10	Architect	Architect	5
11	Civil Engineer	Project's supervisor	6
12	Civil Engineer	CEO	7
13	Civil Engineer	President	8
14	Civil Engineer	Project coordinator	9
15	Architect	Architect	10
16	Architect	Architect	11
Interview to evaluate BIM projects			
17	Civil Engineer	Project Manager	12

4.4.3 Interviews design

Initially, to attain the third objective of this study, two interview guides were designed (Refer to Figure 4.14). The first one was directed to Dominican construction organisations in which was intended to appraise and document BIM awareness and BIM implementation. Eleven interviews were conducted following this interview guide. The second interview guide aimed to analyse the implementation of BIM in construction projects. Only one interview following this interview guide was undertaken to evaluate the implementation of BIM in a hospital in the Distrito Nacional, one of the only precedents of BIM implementation in the country identified by the researcher prior undertaking this research (Despradel, 2015).

Directed to construction organisations
•11 interviews •11 organisations •16 interviewees

Evaluate BIM projects
•1 interview •1 organisation •1 interviewee

Figure 4.14 Interview guides in the preliminary study

The interview guide directed to construction organisations was designed in two sections (Refer to Figure 4.15). The first section aimed to explore the characteristics of the organisations by enquiring general information. The second section aimed to investigate the awareness and implementation of BIM in the organisation. The interview guide considered two alternatives for this section. When organisations were not related to BIM at all, the researcher would investigate the reasons why BIM has not been considered and get their insight about the implementation of BIM. On the other hand, when the organisations were involved with the implementation of BIM, the interview aimed to elicit specific aspects of the implementation. Furthermore, the challenges as to BIM implementation in the country would also be explored from the interviewee's insight regardless of their involvement with BIM (Refer to Appendix 4-C to see the interview guide).

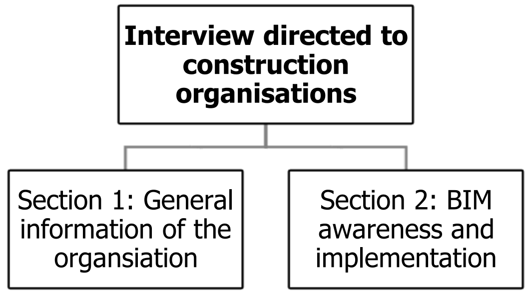


Figure 4.15 Structure of interview guide directed to construction organisations

The interview guide designed to evaluate BIM projects consisted of two sections as well (Refer to Figure 4.16). The first one intended to collect general and non-BIM-related information about the project. The second section consisted of a comprehensive section that aimed to evaluate multiple aspects of the implementation of BIM in the project. In essence, the reasons for the implementation, standardisation, software use, BIM dimensions, BIM uses, BIM benefits and problems in the implementation to name a few.

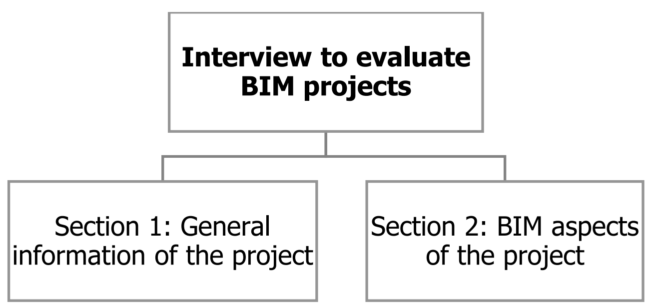


Figure 4.16 Structure of interview guide to evaluate BIM projects

4.4.4 Abductive content analysis

This section aims to present in more detail the content analysis approach undertaken in the preliminary study.

The researcher decided to adopt an abductive approach for the preliminary study as it appeared to be the most appropriate way to draw information from the interviewees to achieve the third and fourth objective set at the beginning of the research (Refer to Section 4.4.1). The researcher considered that an inductive approach would be appropriate for the third objective of this study (i.e. To critically appraise and document the BIM awareness and implementation in the Dominican construction industry). On the other hand, a deductive approach was considered for the fourth objective defined in the preliminary study (i.e. To identify and document the challenges hindering the implementation of BIM in the Dominican construction industry). This approach was adopted because the researcher was not sure at the beginning of the research process if the level of BIM knowledge of the interviewees would be enough to identify the challenges as to BIM implementation.

The inductive approach adopted for the whole study was discussed in Section 4.3.3.1. Therefore, this section will cover only deductive approach as part of the abductive approach adopted in the preliminary study.

As previously stated, the deductive approach was carried out exclusively to explore the BIM challenges as to BIM implementation. For that, the researcher listed key challenges identified in the literature (Refer to Table 4.6). Interviewees had to identify the challenges and indicate their level of importance for their organisations as follows: very high importance, high importance, medium importance, low importance, very low importance and none importance. This approach was adopted to help interviewees with limited BIM knowledge to be able to identify BIM challenges that they did not know. Also, through the level of importance, the researcher intended to see the degree of impact of these challenges. Interviewees would be asked subsequently to comment about the challenges to get their insight on the topic.

Table 4.6 Challenges to BIM implementation identified in the literature

Challenge	Reference from literature
High investment	(Yan and Demian, 2008; Becerik-Gerber *et al.*, 2011; Azhar, Khalfan and Maqsood, 2012; Brewer and Gajendran, 2012; Czmoch and Pękala, 2014; Liu *et al.*, 2015; Mills, 2015)
Cultural resistance	(Yan and Demian, 2008; Arayici *et al.*, 2011a; Becerik-Gerber *et al.*, 2011; Azhar *et al.*, 2012; Mills, 2015)
Lack of BIM skilled personnel	(Aouad, Wu and Lee, 2006; Fox and Hietanen, 2007; Mihindu and Arayici, 2008; Arayici *et al.*, 2011a; Azhar, *et al.*, 2012)
Learning curve	(Azhar*et al.*, 2012; Zahrizan *et al.*, 2013)
Lack of demand	(Lymath, 2014; Mills, 2015)
Lack of BIM guidelines and regulations	(Azhar, 2011; Liu *et al.*, 2015)
Lack of top management support	(Eadie *et al.*, 2013b; Aladag, Demirdögen and Isık, 2016)

For the organising phase in a deductive approach, Elo and Kyngäs (2008) proposed the use of a categorisation matrix in which the categories are listed, and data is coded accordingly. The researcher created nodes instead in NVivo software for each challenge and coded comments that the interviewees made in this regard. Furthermore, a list of the ranking for each challenge given by the interviewees was created as presented in Table 4.7. The researcher then proceeded to review the data and reported the results in a written manner.

Table 4.7 Challenges identified deductively in the preliminary study

Challenges	Very high importance	High importance	Medium importance	Low importance	Very Low importance	Non-importance	Total
High investment	2	2	3	0	2	2	11
Cultural resistance	2	3	4	1	1	0	11
Lack of BIM skilled personnel	0	3	5	0	1	2	11
Learning curve	0	1	6	3	0	1	11
Lack of demand	3	2	1	2	2	1	11
Lack BIM guidelines regulations	7	2	1	0	1	0	11
Lack of interest	0	2	1	2	0	6	11

4.4.5 Impact of the preliminary study to the main study

The preliminary study enabled the researcher to test the effectiveness of the research approach adopted to fulfil the research objectives. Several changes to the main study were considered, which are discussed below.

4.4.5.1 Exclusion of interviews directed to BIM projects

Even though interesting results were elicited from the interview about the BIM project, this approach was discarded in the main study for various reasons. Firstly, to make this approach more effective and get a broader perspective of the implementation of BIM at a project level in the country, the researcher had to evaluate several projects. Nonetheless, it was challenging to find BIM projects in the country. There was only another reference of a project where BIM was allegedly implemented, and two projects appeared to be insufficient sampling to make a relevant analysis. Additionally, the implementation of BIM at a project level is conditioned by several factors such as size and type of company; size and type of project; capability of project participants, etc. Hence, it was concluded that evaluating projects would provide polarised data that may not contribute significantly to the aim of this research.

4.4.5.2 Adoption of inductive content analysis for the whole study

The preliminary study adopted an abductive approach. Most of the aspects of the interviews were analysed inductively, excepting the challenges as to BIM implementation in which the researcher presented a list to several challenges found in the literature so the interviewees could identify and rank them and subsequently talk about them. When the challenges were presented to the interviews, most of them made relevant comments about them which indicated that they were able to answer this question with an inductive approach. Hence, the researcher decided to adopt a complete inductive approach in the main study to have more consistency in the research. Only the results from the main study are used to report the challenges as to BIM implementation in the country in order to avoid data contamination (Kim, 2011) (Refer to Chapter 7).

4.4.5.3 Interview guide

The interview guide was refined by improving, eliminating and adding questions. Details on the refinement are provided in section 4.5.2.

4.4.5.4 The inclusion of the study of BIM education in the country

BIM education was an important theme that emerged in the preliminary study. First, it arose from the identification of lack of BIM skilled personnel as an important challenge to BIM implementation in the country. Secondly, there were identified initiatives of BIM education in the country: a training centre teaching some aspects of BIM in their software courses and the interest of integrating BIM into a university curriculum. Furthermore, the literature review indicated the importance of BIM education in enabling the implementation of BIM in a country. These findings suggested exploring this subject further. Therefore, a new objective was included: "To explore and document the presence of BIM Education in the country". For that, a new interview guide was designed, which is explained in detail in Section 4.5.2.

4.5 Main study

This section aims to describe the unique aspects of the main study by providing specific details related to the data collection and how the interviews of this phase were designed. It also explains why the research outcome evolved from a toolkit to a framework in this phase.

4.5.1 Data collection details

4.5.1.1 Timeline

This study was conducted from the 4th of December of 2016 to the 17th of January 2017.

4.5.1.2 Participants characteristics

The profile of the interviewees from construction organisations that participated in the main study is presented in Table 4.8.

Table 4.8 Profile of the interviewees that participated in the interviews directed to construction organisations in the main study

Interviewee	**Profession**	**Role in the organisation**	**Org.**
18	Civil Engineer	Cost estimation, construction planning and project supervision	13
19/A*	Civil Engineer	BIM Coordinator	14
20	Architect	BIM Coordinator	12
21	Civil Engineer	Project's control	12
22	Civil Engineer	Junior Resident Engineer	15
23	Civil Engineer	Board's President and General manager	12
24	Civil Engineer	Tekla BIM Coordinator	16
25	Civil Engineer	Area coordinator (Resident Engineer)	16
26	Architect	Manager of the Architectural Department and BIM coordinator at one project	12
27	Civil Engineer	BIM Manager and BIM Coordinator	17
28	Architect	Dir. of the Architectural Department	18
29	Architect	Architect	18
30	Civil Engineer	General Project Manager	19
31	Civil Engineer	Project Manager	20
32	Architect	Owner and in charge of the Architectural Design	21
33	Architect	Relocation planning manager of an Urban regeneration project	22
34	Civil Engineer	Project manager	23
35	Architect	Owner	24
36	Architect	Director of the drawing department	25
37	Architect	Technical director	26
38	Architect	Executive director	27
39	Architect	Manager director	27
40	Civil Engineer	Project manager	28

41	Architect	General manager	29
42	Civil Engineer	Technical Engineer	30
43	Architect	Owner and Project's director	31
44	Architect	Owner and Project's director	31
45/H*	Civil Engineer	Director and Project manager	32
46/I*	Architect	Director and Project manager	32
47	Architect	Supervision of the procurement of materials and as-built models. Supervision of the construction.	33
48	Civil Engineer	Cost Estimation and Project Planning	34
49	Civil Engineer	Owner of the company and Construction Manager	35
50	Architect	President of the company	36
51	Architect	Architect in Supervision and construction	36
52	Civil Engineer	In charge of construction	36
53	Civil Engineer	Construction assistant	36

To conclude, Table 4.9 presents the profile of the interviewees that participated in the interviews related to BIM Education.

Table 4.9 Profile of the interviewees that participated in the interviews related to BIM education

Interviewee	**Profile**
Int. 19/A*	Civil Engineer and MSc in BIM.
B	Architecture Technician
C	Civil Engineer. Professor and Researcher at University A.
D	Architect. Founder member of Training Centre C.
E	Architect. Director of the Continuing Education Department of the Headquarters of Professional Body A.
F	Architect. Professor at University C, CEO of Training Centre A, and exclusive Vectorworks provider
G	Freelance Architect.
Int. 45/H*	Civil Engineer. Professor at University A.
Int. 46/I*	Architect

*Interviewees that participated in the interviews to construction organisations and the interviews related to BIM education

4.5.2 Interviews design

The interviews directed to construction organisations kept the structure from the preliminary study. The interview guide was refined to attain the research objectives more effectively. It is worth mentioning the addition of two questions that were key in the development of the framework (initially intended to be a toolkit):

- *Which actions do you think are necessary for the Dominican Republic to propel the implementation of BIM?* and
- *In your view, do you think that the development of a toolkit to guide the implementation of BIM would be beneficial for the Dominican construction industry?*

Please, refer to Appendix 4-D and to Appendix 4-H to see a transcribed interview from the main study.

On the other hand, a new interview guide related to BIM education in the country was developed. This interview guide was designed to evaluate the involvement of the interviewees with BIM education. Important aspects were explored such as how they got interested in BIM, how they acquired knowledge about BIM, how they started to get involved with BIM education and the manners in which they are related to BIM education. Other topics that the interview guide aimed to explore were their projects concerning BIM education; challenges they perceive; and the actions they consider necessary to propel the implementation of BIM in the country (Refer to Appendix 4-E).

4.5.3 Research outcome: Framework

During the main study, findings drawn from the data analysis indicated that the outcome of the research should provide strategies to facilitate the implementation of BIM in the country rather than supporting decision-making. Furthermore, these strategies could be well developed in the form of a framework, not strictly with a toolkit. Hence, the outcome of the research evolved from "Decision support toolkit' to a "Framework", whose development is explained in detail in Chapter 8. This decision required to change the last objective of this research to the following: "To develop and validate a framework to facilitate the implementation of BIM in the Dominican construction industry".

4.6 Synopsis of the research strategy

Table 4.10 summarises the research strategy of both phases of the study.

Table 4.10 Research strategy of the preliminary study and main study

Research aspects	Preliminary study	Main study
Timeline	4th-16th of January 2016	4th of December 2016-17th January, 2017
Sampling	Purposive sampling	Purposive sampling
Sample universe	• Construction organisations in the Dominican Republic • Construction projects where BIM has been implemented	• Construction organisations in the Dominican Republic • BIM Education/training stakeholders
Sampling strategy	Snowball sampling	Snowball sampling + online search
Interviews	• Semi-structured interviews to evaluate construction organisations with respect to BIM awareness and implementation • Semi-structured interviews to	• Semi-structured interviews to evaluate construction organisations with respect to BIM awareness and implementation • Semi-structured interviews to explore the status of BIM Education in the

	evaluate BIM projects	country
Number of interviews	• Directed to construction organisations: 11 • BIM project: 1	• Directed to construction organisations: 28 • BIM education: 8
Number of interviewees	17	42
Number of construction organisations	12	25*
Data analysis	Abductive content analysis	Inductive content analysis

* Org. 12 participated in both studies. In the preliminary study to evaluate a BIM project which was later discarded, and then in the main study for the interviews directed to construction organisations.

4.7 Summary

This chapter provided an overview of the research methodology adopted in this study. This study followed a pragmatic worldview from which a qualitative approach was selected for the research design mainly due to the paucity of research on BIM implementation and on the construction industry itself in the Dominican Republic. Semi-structured interviews were the research method selected for data collection, whereas content analysis was the method chosen for data analysis.

This research was carried out in two phases. The first phase of the study, namely, preliminary study, enabled the researcher to guide the research and refine the data collection for the main study, which corresponds to the second phase of the study. Details on the sampling, data analysis process, and how its trustworthiness was ensured have been provided. Both phases of the research are explained in detail. The impact of the preliminary study to the main study was described for a better understanding of the changes experienced in the research process.

In total, 36 construction organisations and 59 professionals participated in the interviews reported in this study: interviews directed to construction organisations and interviews related to BIM Education. Results from the qualitative analysis carried out in this study are presented in Chapter 5, 6, 7 and 8.

CHAPTER 5: STATUS OF BIM IN THE DOMINICAN CONSTRUCTION INDUSTRY

5.1 Introduction

This chapter discusses the results from the preliminary study and main study on the status of BIM to achieve the third objective of this study which is *"To critically appraise and document the BIM awareness and implementation in the Dominican construction industry"* (Refer to Chapter 1, Section 1.2).

In both phases of the study, the researcher interviewed professionals from construction organisations to enquire about BIM. As explained in the methodology chapter, the criteria to select the organisations did not mandatorily require that they were implementing BIM, as it was expected not to find many organisations that do so. Due to this approach, there are different types of organisations concerning their involvement with the implementation of BIM. They were classified into three groups: organisations that do not implement BIM, organisations in transition to implementing BIM and organisations implementing BIM.

Through the organisations that do not implement BIM, the researcher could evaluate why these organisations do not implement BIM and discern their insight on the topic. On the other hand, the organisations in transition to implementing BIM and implementing BIM allowed the researcher to analyse which aspects they are considering for the implementation of BIM: what they are doing correctly, what they are lacking and what they need to do to improve their current strategies. Furthermore, with the organisations implementing BIM, more specific aspects of the implementation of BIM could be drawn, which allowed the researcher to detect deficiencies in their approaches. An evaluation of this kind was beneficial to determine which factors are needed to develop a framework that can meet the needs of the Dominican construction industry and drive the implementation of BIM.

The analysis discussed in this chapter is presented in two sections. The first section (Section 5.3) presents the findings on BIM awareness from all the interviewees that belong to the construction organisations. The second section (Section 5.4) presents the analysis of the status of BIM implementation. It starts with the findings from the organisations that do not implement BIM. It discusses the reasons why they do not implement BIM, their openness to implementing it, and what would motivate these organisations to implement BIM in the future. Then, findings from the organisations in transition to implementing BIM and implementing BIM are presented. Their engagement with BIM is explored through aspects such as their motivation to implement BIM; BIM implementation strategies; and the issues affecting their current involvement with BIM. To conclude, the chapter presents the findings from the organisations implementing BIM where aspects more intrinsically related to BIM such as the scope of BIM implementation, resources for implementation and perceived benefits are discussed.

5.2 Construction organisations characteristics

A total of 36 construction organisations participated in the whole study. The organisations were classified according to their size following the Dominican *Law no. 488-08* (Fernandez, 2008), which defines Micro, Small and Medium Enterprises by their number of employees, assets and turnover, as presented in Table 5.1. The participants did not provide information about the assets and turnover; therefore, the classification was based only on the number of employees. The organisations with a larger number of employees than the ones specified in this classification were classified as large enterprises.

Table 5.1 Classification criteria for Micro, Small, and Medium Enterprises according to the Dominican Law 488-08

Source: Fernandez (2008)

Company classification	Number of employees	Assets	Turnover
Microenterprise	1 to 15	Up to RD$3,000,000.00	Up to RD$6,000,000.00
Small Enterprise	16 to 60	RD$3,000,000.01 to RD$12,000,000.00	RD$6,000,000.01 to RD$40,000,000.00
Medium Enterprise	61 to 200	RD$12,000,000.01 to RD$40,000,000.00	RD$40,000,000.01 to RD$150,000,000.00

Microenterprises represented the biggest group of the study, with 18 organisations representing 50% of the sample. Small enterprises were the second largest group, with 9 organisations accounting for 25% of the sample. Lastly, medium and large enterprises were the minority, representing 11% and 14% of the sample, respectively (Refer to Table 5.2).

Table 5.2 Classification of the construction organisations of the study according to their size

Org. According to their size	Micro-enterprise	Small enterprise	Medium enterprise	Large enterprise
Number of organisations	18	9	4	5
Percentage	50%	25%	11%	14%

The sampling of this study represents the actual composition of the Dominican construction industry. According to ONE (National Office of Statistics) (2017), 3,888 construction companies were registered in the D.R. by 2016. These companies were classified according to the number of employees; however, the employees' ranges used in this statistic are not by the Law 488-08 previously mentioned. Despite this difference, it is evident that most of the construction companies in the Dominican Republic are micro-enterprises. As presented in Table 5.3, more than 81.83% of the organisations are micro-enterprises, which represents the majority; whereas large (201 employees or more) and medium (61 to 200 employees) and small enterprises (16 to 60 employees) comprehend the minority in the industry. Please refer to Appendix 4-F to see relevant information regarding the construction organisations that participated in this study.

Table 5.3 Number of construction companies in the Dominican Republic and their number of employees

Source: ONE (2017)

Number of employees	Number of companies	Percentage
1-9	3,161	81.30%
10-29	497	12.78%
30-49	89	2.29%
50-99	64	1.65%
100-249	47	1.21%
250-more	30	0.77%
Total	3,888	100%

5.3 BIM Awareness

Awareness is defined as *"the knowledge that something exists, or understanding of a situation or subjects at present based on information or experience"* (Cambridge University Press, 2017). If applied to the context of BIM, BIM awareness is simply the state whereby an individual or organisation knows of the existence of BIM through information retrieved or received from others in their environment or through their own experience (e.g. by implementing it). This study explored the BIM awareness of the professionals belonging to the construction organisations that participated in this study. Interestingly, BIM awareness appeared to be very high among the 53 interviewees from the participant construction organisations. 89% of the interviewees (47 out of 53) were aware of BIM, in contrast to an 11% (6 out of 53) that were not aware of BIM when the interviews were conducted.

It is important to note that the BIM awareness percentage was higher among the interviewees of the main study. In the preliminary study, 5 out of the 17 participants from 3 organisations stated not to be aware of BIM. In contrast, in the main study, only 1 out of the 36 participants said not to have heard about BIM before being interviewed.

The increased level of BIM awareness in the main study can be attributed to different factors:

- **Time when interviewees were conducted:** The preliminary study was conducted in January 2016, and the main study was done a year later, between December 2016 and January 2017. At the beginning of 2016, the topic of BIM was not as popular as it was in late 2016 and beginning of 2017 in the country, period in which the main study was planned and carried out. During this period, several BIM events were held in the capital of the country, and BIM Diploma courses were delivered in different cities. Moreover, various software providers started to focus on BIM, and professionals began adding BIM as part of their competences and services in platforms such as LinkedIn.

- **Improved networking:** People aware of BIM in the main study referred to the researcher people not only aware of BIM but also very interested in the topic and even in the path of BIM implementation, a situation that did not often happen in the preliminary study. It is important to note that the inclusion of interviews about BIM Education helped significantly on this aspect. Ten participants of the main study were interviewed about the diffusion of BIM knowledge in the country; therefore, they were aware and quite knowledgeable about BIM. Some of them referred people with BIM knowledge, and interested in the topic or partially implementing BIM (i.e. Int. 36 from Org. 26 and Int. 47 from Org. 34).

5.4 Status of BIM implementation in the country

As presented in Table 5.4, the organisations that participated in the current study were classified according to their involvement with BIM in organisations not implementing BIM, organisations in transition to implementing BIM and organisations implementing BIM.

Table 5.4 Classification of the construction organisations according to their involvement with BIM

Classification according to their involvement with BIM	**Organisations**	**Total of organisations (N=36)**	**Percentage (No. of organisations/ total no. of organisations x 100)**
Organisations that do not implement BIM	1, 2, 3, 4, 6, 7, 8, 9, 10, 14, 15, 20, 22, 23, 27, 28, 29, 30, 33, 34, 35, 36	22	61%
Organisations in transition to implementing BIM	5, 13, 19, 25 and 31	5	14%
Organisations implementing BIM	11, 12, 16, 17, 18, 21, 24, 26 and 32	9	25%

Organisations that do not implement BIM are organisations that do not implement any BIM-related process in their practices. This category also included organisations whose CEO's and directors had not made any organisational changes to adopt BIM yet. Twenty-two organisations were allocated in this category, which accounts for 61% of the organisations that participated in the study.

The remainder organisations were involved with BIM but to different extents. Organisations interested in BIM which had already made the decision of implementing BIM and were going through some changes to attain this goal were categorised as *organisations in transition to implementing BIM*. Five organisations were allocated in this category, accounting for 14% of all the organisations that participated in the study. Furthermore, organisations whose leaders and employees had a broad BIM knowledge, and which had some BIM-related processes in their practices were categorised as *organisations implementing BIM*. None of the organisations in this category fully integrate BIM in all their business processes. Instead, this classification took into consideration organisations that implement BIM-related processes either in a single or multidisciplinary approach and in other business processes. Nine organisations were allocated in this category, which accounts for 25% of all the organisation involved in the study. The main difference between the organisations in transition to implementing BIM and the organisations implementing BIM is that the first ones recently embarked on the BIM journey, while the latter were already implementing BIM and their leaders and employees were more knowledgable on BIM.

This classification and the number of organisations on each of category indicate that the implementation of BIM in the participant organisations was low as almost two-thirds (61%) were not implementing BIM.

The next sections will present the findings of the study according to these three types of organisations.

5.4.1 Organisations that do not implement BIM

In response to the question *"Is BIM implemented in this organisation?"*, nine organisations from the preliminary study (Org. 1, 2, 3, 4, 6, 7, 8, 9 and 10) and thirteen organisations from the main study (14, 15, 20, 22, 23, 27, 28, 29, 30, 33, 34, 35 and 36) stated not to be implementing BIM in their practices. This section presents the findings that could be elicited from these organisations.

5.4.1.1 Reasons why BIM is not implemented in the organisations

Through the question "*Why is BIM not implemented in this organisation?"*, this study explored the reasons why these organisations were not implementing BIM. In a few cases, interviewees provided more than one reason for the researcher. Aided by the method of content analysis, these reasons were categorised in Intra-organisational and Inter-organisational reasons (Refer to Figure 5.1).

It is important to note that two of these organisations that do not implement BIM expressed to be very interested and getting ready to start transitioning; therefore, they did not provide any reasons as the rest of the organisations. Interviewee 46 from Org. 33 informed that the organisation already had a plan to train the personnel for this purpose. Furthermore, Interviewee 48 from Org. 34 said that the organisation already had a BIM proposal prepared by an external expert (Interviewee G) that had to be shown to the CEO for its approval.

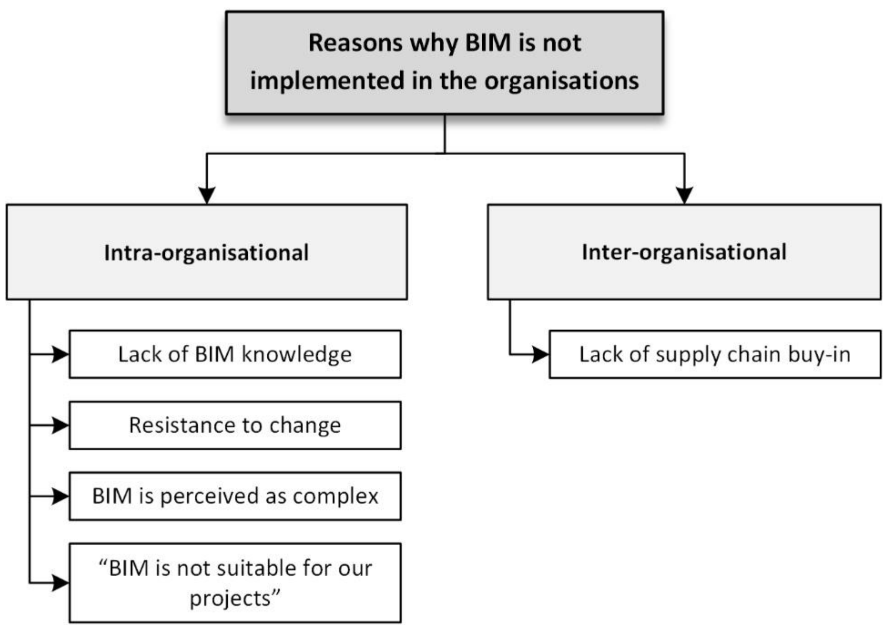


Figure 5.1 Reasons why BIM is not implemented in the organisations

5.4.1.1.1 Intra-organisational reasons

The intra-organisational reasons identified by the interviewees include: Lack of BIM knowledge, Resistance to change, BIM perceived as complex, and "BIM is not suitable for our projects".

5.4.1.1.1.1 Lack of BIM knowledge

Lack of BIM knowledge was the most identified reason as to why BIM is not implemented in these organisations, reported by interviewees from 10 of the 22 organisations. The lack of BIM knowledge expressed by the interviewees involved different aspects. First, lack of BIM awareness from leaders was identified in 2 organisations: *"If you mention them BIM, they will not know what it is"* - Interviewee 1. Furthermore, leaders from six organisations were aware of BIM but had limited understanding of what BIM implies and the benefits of its implementation. In this regard, Interviewee 19/A indicated: *"I think they do not know the power these tools have and how much they can help on-site in the construction process*".

Org. 27 and 36 are quite interested in implementing BIM. However, they stated they have not been able to do it because of the lack of knowledge on how to develop a plan to attain this goal: *"There are many things that you need to study to implement BIM. We need to look into that [...] We want to implement it in our company, and we are aware that there are certain aspects and workflows that we need to implement to achieve this goal"* – Interviewee 39, Org. 27.

5.4.1.1.1.2 Resistance to change

Resistance to change traditional methods and adopt BIM can be caused either by user's unawareness or dissatisfaction of BIM benefits and advantages (Batarseh and Kamardeen, 2017). Interviewees from 4 organisations reported this attitude towards BIM. Two interviewees expressed that the leaders of their organisations were resistant to implement BIM because they were entrenched to traditional methods. For instance, Interviewee 11 from Org. 6 stated: *"There is not any interest of implementing BIM in this institution because they are in a comfort zone in the way they are working at the moment"*. Also, Interviewee 22 from Org. 15 opined that the organisation would not change because they were already successful without implementing BIM: *"…because they have been successful, and what they do is being effective, they haven't felt the need of implementing BIM"*. Lastly, Interviewee 40 from Org. 28 stated that the organisation does not want to implement BIM because, currently, they do not consider this change is essential.

5.4.1.1.1.3 BIM perceived as complex

Complexity is defined by the extent to which the innovation is considered as difficult to understand and use and represents a fundamental indicator of innovation adoption. The perceived complexity of innovation from members of a social system has a negative impact on its adoption rate (Rogers, 1995). If innovation is seen as difficult to learn and implement, individuals are prone to perceive it as less beneficial because they probably would not be very proficient when using it (Xu *et al.*, 2014). BIM is being described as a complicated process by several studies. Moreover, BIM software has been considered as too complex (Xu *et al.*, 2014; Ahuja *et al.*, 2016) and a hurdle to spread the adoption of BIM (Xu *et al.*, 2014).

In that respect, two interviewees from two organisations stated that BIM is not implemented in their organisations because the process and software used for the implementation are perceived as complex. Interviewee 15 from Org. 10 argued: "*…my boss, who still uses AutoCAD, and the office, which has a system, didn't want to start implementing complex things such as BIM because if at any moment we leave the company and they need to revise a project, they won't understand the system".*

5.4.1.1.1.4 "BIM is not suitable for our projects"

Many individuals may be aware of numerous innovations that they have not decided to adopt yet. One reason for this decision can be that the innovation may not appear to be important or beneficial within their circumstances. That infers that attitudes on an innovation usually mediate between the knowledge and decision-making functions (Rogers, 1995). That is the case of interviewees from two organisations which acknowledged that the implementation of BIM is very beneficial. Nonetheless, they do not think it is suitable for the type of projects they usually develop: *"It is not worth it for us to implement BIM for a plant treatment, but for a complex project such as an airport… its implementation is totally worth it"* – Interviewee 42, Org. 30.

5.4.1.1.2 Inter-organisational reasons

5.4.1.1.2.1 Lack of supply chain buy-in

Interviewees from five organisations pointed out that they do not implement BIM because of the members of the supply chain. As per Interviewee 14 from Org. 9, BIM has never been required by members of the supply chain; while Interviewee 41 from Org. 29 commented that many of the designers they work with do not have BIM knowledge. In terms of software, interoperability issues and lack of BIM software skills were mentioned by four out of the five organisations: *"We don't have the necessity of implementing BIM because if the ones we subcontract feel comfortable with an X software, we can't force them to use BIM. It would be better if they implemented BIM"* – Interviewee 40, Org. 28*.*

5.4.1.2 Openness to implementing BIM

Despite their current lack of involvement with BIM, interviewees were asked if the implementation of BIM would be considered for the organisations in the future to gauge their openness to implementing BIM. The responses were mainly positive as interviewees from 16 out of 22 organisations (73%) stated that the implementation of BIM could be considered in the organisations in the future.

On the other hand, interviewees from three organisations said the organisations would not consider the implementation of BIM in the future. Interviewee 2 from Organisation 2 argued that *"We work for us, we manage the time as we want, there is no person that asks us something. The BIM technology is very easy, is feasible, it saves you time and makes you work correctly, but what happens? This process is suitable for an* *enterprise that is always working…"* inferring that the implementation of BIM is not for organisations like Org. 2 where the organisation is their own client and the project's demand is not constant.

Moreover, Interviewee 2 explained *"Also we do not tend to execute big projects, small projects do not need BIM",* suggesting that BIM is just for large projects, as also reflected by Ramilo (2014). In the same manner, Interviewee 12 from Organisation 7 stated: *"If this company were big, I would look for the personnel and would train them according to my interests"*, pointing out that the size of the organisation and the lack of BIM skilled personnel in the organisation and the Dominican construction industry affects this decision significantly. On the other hand, despite recognising that the implementation of BIM would be beneficial for the organisation, Interviewee 22 from Organisation 15 said that *"They won't see the need of changing their method if they are successful already… And believe me, they are successful and have a lot of projects*", inferring that this organisation needs another motivation for implementing BIM rather than the productivity and competitiveness in the market, as its leaders consider they are in a good position already.

Lastly, interviewees from three organisations expressed they are not sure if BIM could be implemented in the organisations in the future.

It is important to note that two organisations were thinking of making the transition to BIM. Interviewee 46 from Org. 33 informed that the organisation already had a plan to provide Revit training for the personnel for this purpose. Furthermore, Interviewee 48 from Org. 34 said that the organisation had a BIM proposal to be shown to the CEO for its approval.

These results suggest that there is a general interest in BIM in the Dominican Republic, as only 17% of the organisations (3 out of 22 organisations) stated to be not interested in implementing BIM. Hence, the development of a framework to facilitate the implementation of BIM would be indeed beneficial to assist those organisations interested in implementing BIM.

5.4.1.3 Potential drivers for BIM implementation

As previously presented, interviewees from organisations where BIM is not implemented were enquired about their organisation's openness to implementing BIM. Following the question *"Would this organisation consider the implementation of BIM in the future?"*, interviewees that answered positively were asked why the organisation would make this decision. In response to this question, interviewees indicated which potential drivers would encourage the implementation of BIM in the organisations in the future: BIM benefits and competitive advantage.

5.4.1.3.1 BIM benefits

BIM benefits are intrinsically drivers to its implementation (Eadie *et al.*, 2013b). 10 out of 16 organisations that do not implement BIM but are opened to do so stated that BIM benefits may be the stimulus if the implementation is considered in the future. Most of the interviewees were quite general when talking about which BIM benefits may motivate the implementation of BIM in the organisations. Explanations were primarily related to being aware of the benefits that BIM can offer to their workflows, and the enhancements they can realise in terms of efficiency, time, facilitation of work, etc. Additionally, Interviewee 15 from Org. 10 mentioned benefits such as automatic low-level corrections and production of schedules, which are benefits related to the parametric features of BIM software, rather than the BIM process itself. These statements denote a limited knowledge of the whole scope of BIM implementation.

5.4.1.3.2 Competitive advantage

A firm has a competitive advantage when it is adding a value that none of its potential or current competitors has (Barney, 1991). Competitive advantage refers to the aspect of the firm which is difficult to imitate and sustained in the future, which positions the firm over its competitors and promotes better business performance (Kamukama *et al.,* 2017). Economic innovation and innovation adoption by firms has been explained as a reasonable financial practice to seek sustainable competitive advantage (Brewer and Gajendran, 2012). Regarding the construction industry, Alshawi *et al.* (2010) contended that construction organisations had felt the need to implement technology to stay competitive. The desire for innovation to remain competitive has been identified as a critical driver to BIM adoption (Eadie *et al.*, 2013b). Also, it is believed that more competitive pressure has a positive impact on BIM adoption rates (Ahuja *et al.*, 2016).

The competitive advantage that is reached when implementing BIM was another driver identified by the 9 out the 16 organisations of this study that do not implement BIM yet willing to do it in the future. In this regard, Interviewee 13 from Org. 8 argued that "…

(BIM) places you in a different position in the market, in a competitive place. At a competitive level is not the same having a 2D rather than a model. You cannot compare", reflecting a misconception of the competitive advantage that BIM can offer, as it is only considered the use of a 3D model.

5.4.2 Organisations in transition to implementing BIM and implementing BIM

As previously explained, five organisations were categorised as organisations in transition to implementing BIM, and nine organisations were categorised as organisations implementing BIM, accounting for 25% of the organisations of the study. The next sections will present the analysis of both types of organisations as regards their involvement with BIM.

5.4.2.1 Drivers for BIM implementation

In response to the question *"What has motivated this organisation to implement BIM?"*, interviewees from organisations in transition to implementing BIM and those currently implementing some BIM aspects explained which drivers have encouraged the organisations to start and continue with the implementation of BIM. The responses were quite similar to the ones provided by interviewees from organisations that do not implement BIM. 'External pressure' was the only different driver mentioned by the interviewees.

5.4.2.1.1 BIM Benefits

Interviewees from 3 organisations in transition to implementing BIM and 8 organisations already implementing BIM stated that their primary motivation is the benefits they can obtain through the implementation of BIM. A few of the interviewees from these organisations were very specific when talking about which BIM benefits have stimulated the transition and current implementation of BIM, including the following benefits:

- Alignment of the design of different disciplines (Org. 12 and 36)
- Discovery of design errors before the construction phase (Org. 12 and 26)
- Beneficial for large projects (Org. 11)
- Advantages of the use of BIM software (Org. 5 and 12)
- Proven benefits worldwide (Org. 12)
- Work faster (Org. 24)
- Accurate representation of the planned project (Org. 32)

It can be noted that many of the distinct benefits specified by the interviewees are realised in the design and construction phase of a project (Sacks *et al.*, 2018). That may infer that either their knowledge on the benefits of BIM is limited or that the organisations are interested in implementing BIM to improve their workflows and productivity only in these two phases, not throughout the project's life cycle.

5.4.2.1.2 Competitive advantage

Four interviewees from 4 organisations implementing BIM explained that the motivation to implement BIM in the organisation was to stand out from other organisations that were implementing traditional methods: *"I noticed everyone in the industry offers the same. There is price competition, but there is not much difference and low levels of efficiency in some task. With BIM, you can offer different things"* – Interviewee 27, Org. 17.

5.4.2.1.3 External pressure

Three inter-organisational diffusion criteria describe how individual decision-making can be influenced: contagion, social threshold and social learning. 'Contagion' denotes how an individual adopts an innovation due to the contact with another individual that has previously adopted it. 'Social threshold' indicates that an individual adopts an innovation when plenty of similar individuals have adopted it. And 'social learning' depicts how an individual adopts an innovation when there is sufficient proof from previous adopters corroborating that it is advantageous (Succar and Kassem, 2015). The 'contagion' pattern of innovation was identified in two organisations in transition to implementing BIM and one organisation already implementing BIM, where BIM has been suggested and demanded by external partners. Lee *et al.* (2015) named this type of diffusion "external pressure" and describes it as of the stimulus generated from numerous entities in the competitive environment enclosing the organisation. Influence from other parties has a significant impact on the company's decision to adopt BIM (Ahuja *et al.*, 2016).

Interviewee 18 from Org. 13 stated that the organisation is interested in BIM due to an associate who has introduced it to the organisation. On the other hand, Interviewee 36 from Org. 25 and Interviewee 46/I from Org. 32 explained that BIM had been demanded by international organisations they work with:

> *"Right now we have a project in Punta Cana with a South African company, and they implement BIM like in Europe […] From last year, there have been some projects where BIM has been a requirement. Therefore, the company has considered it a necessity now."*

5.4.2.2 BIM Implementation Strategies of the Organisations

In response to the question *"How did the organisation prepare for the implementation of BIM?"*, organisations implementing BIM explained the organisational changes they have gone through to attain their goal of implementing BIM. Moreover, organisations that stated to be in transition to implement BIM described the strategies they were considering and implementing for these purposes.

5.4.2.2.1 Provision of training

The provision of training was a strategy adopted by almost all the organisations, excepting Org. 5 because their current employees were already skilled in the software they implement for Architecture (i.e., ArchiCAD). As presented in Table 5.5, it can be observed that the organisations have mainly focused on the provision of software training to the employees for the implementation of BIM. Organisations that have not only based their training on software are organisations 12, 16 and 31. Org 12 offered a BIM workshop to all its personnel. Org. 16 provides short inductions in BIM implementation to their new staff. Lastly, Org. 31 had the plan of offering a BIM

Diploma course to their CEOs (Architects) which focuses on Revit but also aims to teach how to implement BIM (Refer to Chapter 6, Section 6.4.2). Another critical aspect that can be drawn is that all the organisations are providing training in Autodesk platforms, being Revit the leading software.

Furthermore, it can also be noted that organisations are providing BIM knowledge and training to particular disciplines and roles in the organisation, especially Architecture related. For example, in organisation 11 are 12, architects have a massive workload because they are the only professionals with BIM modelling skills.

On the other hand, Interviewee 25 from Org. 16 pointed out the lack of consideration of BIM training in minor roles. For instance, site workers of this organisations have not been trained to manipulate the models; therefore, they cannot work on their own when digital models are used for supervision affecting the BIM workflow on projects.

Table 5.5 Training provided for the implementation of BIM in the organisations in transition to implementing BIM and implementing BIM

Organisation	Training	Directed to	Provider	Future training
Organisations in transition to implementing BIM				
Org. 5	N/A	N/A	N/A	N/A
Org. 13	Revit	Architect	Training Centre C	Finish training all the Architects
Org. 19	Basic Revit course	Architects	Technical institution	
Org. 25	Revit Architecture	Architects and Engineers from the Drawing Department	Training Centre with an Autodesk certified professional	For 2017: Revit MEP and Navisworks
Org. 31				January 2017: BIM Diploma course based on Revit delivered by Interviewee G
Organisations implementing BIM				
Org. 11	Revit and Navisworks	Architects	Training Centre with an Autodesk certified professional	

Org. 12	Revit	Architecture Department. Navisworks just Interviewee 26.	Training Centre with an Autodesk certified professional	PMWeb to all the personnel in the office
	In-house workshop in BIM	All the personnel	Training Centre with an Autodesk certified professional	
Org. 16	Tekla		International expert	
	Basic BIM induction (3 days)	New personnel (professionals)	In-house with current personnel	
Org. 17	Revit	Engineers (associates)	CEO (Interviewee 27)	
Org. 18	Revit		Interviewee B	
Org. 21	Revit	Architects and Engineers	CEO (Interviewee 32)	
Org. 24	Revit	Architect	Interviewee 35	
Org. 26	Revit (with certification), Cinema 4D, Photoshop, InDesign	Architecture Department	Interviewee B	
Org. 32	Revit Architecture, Revit MEP and Navisworks	Engineers	In-house training by the CEOs (Interviewee 45/H and 46/I)	

5.4.2.2.2 New Roles

The implementation of BIM entails changes in the roles and responsibilities in the project team. Conventional roles like draftsmen may be substituted by modellers, for example. New roles, such as the BIM manager have been created to ensure better coordination in the functions of developing and maintaining an integrated and multidisciplinary BIM model (Gu and London, 2010). The new roles and responsibilities allocated to the project team need to be outlined with clarity (Jung and Joo, 2011) since lack of clarity on these aspects constitutes a hurdle to its implementation (Gu and London, 2010).

In terms of roles and responsibilities for the implementation of BIM, none of the organisations in transition to implementing BIM mentioned to have plans related to this, and only four out of the nine organisations implementing BIM have made changes related to the designation or creation of new roles. Interviewee 35 from Org. 24 argued that *"Due to the size of the projects we have developed, we haven't"*, indicating that the reason why the organisation has not designated any roles for the implementation of BIM is entirely related to the size of the projects they develop. The changes regarding roles made by the four organisations implementing BIM have consisted mainly in changing the role title of an old position, creating new roles according to the implementation:

- Organisation 11: Creation of the role "Office chief in the Architectural Department", who carries out the duties of what is called BIM coordinator.
- Organisation 12: BIM Coordinators and modellers for different design disciplines. This organisation created a new role called "BIM implementation regulator", who is a person that coordinates that the work on-site is being executed like it is specified in the models.
- Organisation 16: Tekla BIM coordinator, Revit BIM coordinators and Structure Coordinator. The organisation created a role called "BIM Development coordinator", who performs the duties of what is known as BIM Champion (Refer to Chapter 8, Section 8.4.2.2.1.2).
- Organisation 26: This organisation has an associate professional as the BIM champion, who is not called under that name. He does not have a specific role

title. Furthermore, he also performs as the BIM coordinator of the organisation. Interviewee 37 also indicated that due to the implementation of BIM, draughtsmen have a higher status and are called "associates" now. However, this new role title does not relate to BIM.

5.4.2.2.3 Hire skilled personnel

Organisations 11, 12, 24 and 27 stated to have hired staff for the implementation. Organisations 11 and 12 contracted people skilled in Revit. Org. 11 hired personnel in the Architectural design department, while Org. 12 required Revit modellers for different design disciplines. Interviewee 35 from Org. 24 indicated that he hired an Architect who he later trained in Revit. Furthermore, Interviewee 37 from Org. 26 explained that the organisations just hired one person who is currently being the BIM champion and coordinator of the organisation, which has been a significant acquisition for the organisation: *"Yes, the champion, as you named it. It was a key hire"* – Interviewee 37.

Organisations 12 and 18 also stated that when they currently hire people, they take into consideration their software skills: *"If they don't know Revit, we can't hire them" – Interviewee 28 from Org. 18*. On the other hand, in Org. 16 is not considered a must to have either BIM knowledge of being skilled in a BIM software: *"If they know BIM, Excellent! But what they demand is people to know AutoCAD"* – Interviewee 24 from Org. 16.

Furthermore, in their transition process to BIM implementation, Org. 19 is already taking into consideration the BIM competencies of new hires. Interviewee 30 argued: *"I was interviewing a person yesterday that has 16 years in the industry, and he had never heard about BIM […] I may hire him, but I will need to make an investment in training and to explain him the system".* With this statement, the interviewee indicates that hiring people without no BIM knowledge or capabilities is a disadvantage due to the investment in time and money that this represents for the organisation.

5.4.2.2.4 Hardware upgrade

In terms of technology, the only change done for the implementation of BIM was hardware upgrade by Organisations 5 and 19 in transition, and Organisations 11, 12, 16, 18, 24 implementing BIM. That is because they had purchased BIM software before embarking into the BIM journey. The hardware upgrade in all these organisations was in the acquisition of computers with enough capacity to run BIM software and large files. However, besides that, Int. 23 from Org. 12 stated they acquired Microsoft surface to be able to supervise on-site: *"One of the things we did was switching to use surfaces with the intention that Site Engineers use Navisworks to follow up and register things done on-site".* Organisations 25 and 31 stated they would purchase BIM software for design (i.e. Revit) once the training process is complete.

Table 5.6 summarises the different tactics used for organisations in transition to implementing BIM and organisations implementing BIM to prepare for the implementation. It is apparent that in both types of organisations, the provision of training has been the most common strategy implemented.

Table 5.6 Summary of how the organisations prepared to transition/implement BIM

Preparation for the BIM implementation	Organisations in transition to implementing BIM	Organisations implementing BIM
Provision of training	13, 19, 25, 33	11, 12, 16, 17, 18, 21, 24, 26, 32
New roles		11, 12, 16 and 26
Hire people	25	11, 12, 24, 27
Hardware upgrade	5, 19	11, 12, 16, 18, 24, 32

Results show that none of these organisations prepared a thorough plan to implement BIM. They focused on the implementation of BIM software and developed their strategies on the go. As can be noted, the provision of training in all the organisations has consisted in the delivery of software training, more specifically, in Autodesk software. That infers that Autodesk products are currently taking the lead and an OpenBIM approach (Refer to Chapter 3, Section 2.2.3) would be challenging to attain in the country.

5.4.2.3 Issues affecting their current involvement with BIM

Issues that the organisations have experienced in the transition and the implementation of BIM were also explored. It is important to note that interviewee 36 from Org. 25 did not report any issue in the transition process because this organisation was in the training process and had not implemented anything BIM related. The issues reported by the interviewees were of intra-organisational and inter-organisational nature and are broadly explained in the next section.

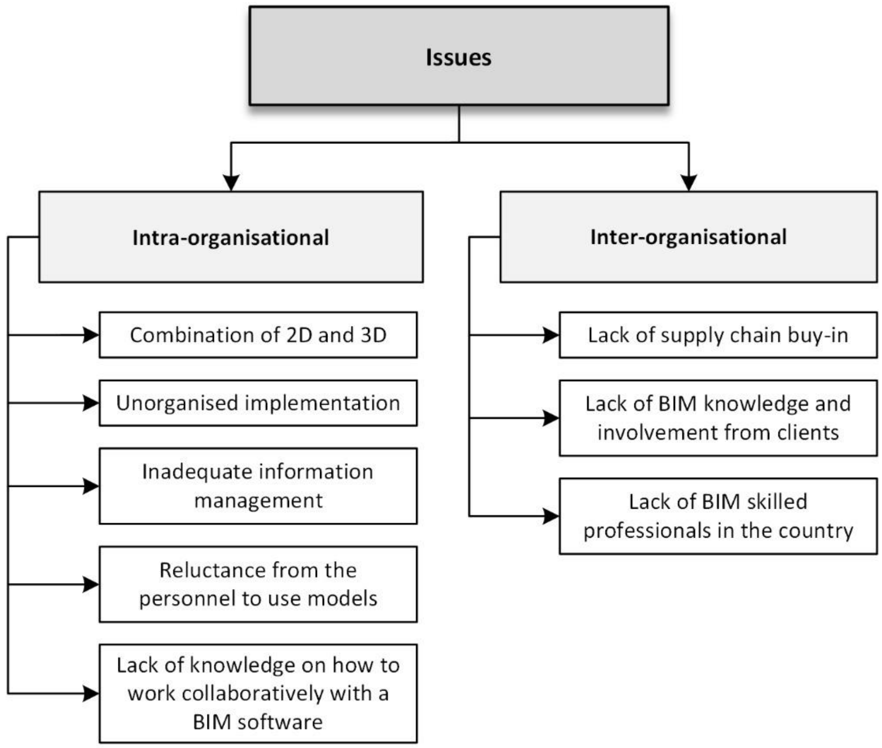


Figure 5.2 Issues affecting current involvement with BIM in organisations in transition to implementing BIM and organisations implementing BIM

5.4.2.3.1 Intra-organisational issues

Interviewees from 2 organisations in transition to implementing BIM and 8 organisations implementing BIM detected intra-organisational issues in their workflows that affect their current involvement with BIM. These include Combination of 2D and 3D software, Unorganised BIM implementation, Inadequate management of information, Reluctance to use models, and Lack of knowledge on how to work collaboratively.

5.4.2.3.1.1 Combination of 2D and 3D software

Interviewees from Org. 5, 11, 13, 16, 18, 21 and 26 stated they still feel the need to use 2D software in the organisations, more specifically AutoCAD 2D, in combination with BIM modelling software, which has affected the flow of information in the development of projects. Interviewees mentioned several reasons as to why this has been necessary:

- **Lack of BIM modelling skills***.* Modellers lack of expertise is one of the main aspects that can cause repetitive work and inefficient BIM implementation (Xu *et al.*, 2014). Org. 5, 13, 16, 17 and 18 identified this problem as a deficiency which has led to delays and mistakes in the 3D models.
- **Facilitate the understanding of the least specialised workers***,* which is caused by the lack of BIM training in minor roles, as previously pointed out by Interviewee 25 from Org. 16 (Refer to 5.4.2.2.1).
- **Interoperability issues among modelling software***.* As pointed out by Interviewee 24 from Org. 16: *"No, ETABS cannot be linked with Revit"*.
- **Lack of BIM-object libraries***.* Interviewee 32 from Org. 21 indicated that they have had to use AutoCAD after using in Revit for Architectural design because of the limited availability of Revit families for their type of projects. In that respect, Enegbuma *et al.* (2014) indicated that the availability of model objects for easy data extraction is essential for BIM to tackle the challenges of the future.

Other reasons as to why 2D software is used in combination with 3D software included the use of 2D *for simple projects* (identified by Org. 16) and *old projects* (identified by Org. 26).

5.4.2.3.1.2 Unorganised BIM implementation

Having an unorganised BIM implementation was an issue identified in the previous section when organisations explained the strategies adopted for the implementation of

BIM. None of the interviewees stated that these strategies were insufficient when describing them. However, when asked about issues in the organisations, interviewees from 4 organisations implementing BIM (16, 17, 18 and 32) stated that they had not organised the implementation of BIM properly. In this respect, Interviewee 25 from Org. 16 commented on this problem reflecting on their organisation but also on the Dominican construction industry: *"We need to learn to program ourselves on time […]this requires an organisation level we are not used to in this country. It might be, but that doesn't mean that is not possible. We can do it".*

Other comments such *as 'Up to now, we are a little creative, a little bit unorganised'* and *'We implement BIM empirically'* also illustrates the tendency of implementing BIM without any planning.

5.4.2.3.1.3 Inadequate information management

Interviewees from Org. 5, 31 and 32 explained they were implementing improper methods for information management. In Org. 5 and Org. 31 the information of the projects is internally shared with USB flash drives. In the case of Org. 5, this is only done by the CEO of the organisation because of his lack of knowledge of using servers: *"Our boss struggles to take the information out of there, and he always carries a portable hard drive and takes the information, put it into the device"* – Interviewee 8. On the other hand, in Org. 31, this is the only method used because they do not have a server in their offices. These approaches contrast with the information management process in BIM, in which digital data and information are produced, stored and managed in a way that teams can collaborate easily and guarantee that the client's information requirements are met (BIM Wiki, 2017).

Furthermore, Interviewees from Org. 32 explained that, when exchanging information with external parties, if the files are massive, they ask for hard-copies because of the deficient internet service in the office: *"The server here is more for administration"*- Interviewee 46/I. They were also re-working due to internal communication deficiencies: *"We got to the point of defining codes for us to work because we did not understand each other, we were working twice".* In that respect, it is relevant to note that classification is critical to attaining effective information management in a BIM project. Moreover. Classification has also been recognised as one of the main components for BIM Level 2 in the UK (BIM Wiki, 2017).

Other deficiencies reported by a minority (1 organisation each) include *reluctance to use models from the personnel* and *lack of knowledge on how to work collaboratively with a BIM software*.

5.4.2.3.2 Inter-organisational issues

Interviewees from 3 organisations in transition to implementing BIM and all the organisations implementing BIM, 12 organisations in total, identified issues of inter-organisational nature caused by Lack of supply buy-in, Lack of BIM knowledge and involvement of the client, and Lack of BIM skilled professionals in the country.

5.4.2.3.2.1 Lack of supply chain buy-in

Melville *et al.* (2004) explained that the implementation of inefficient business processes and obsolete technology from trading partners organisations might impede the goal of an organisation to achieve IT business value in an inter-organisational system. This situation can be equated in the field of BIM. When external stakeholders do not implement BIM or related processes or tools, it affects an organisation's goal of implementing BIM efficiently.

That was the main inter-organisational factor identified by interviewees from the 12 organisations. Interviewees stated that the implementation of BIM had been hindered due to the lack of knowledge and lack of BIM implementation in the construction supply chain. Non-use of BIM software was the main difficulty reported by Interviewees from 3 organisations in transition to implementing BIM and 7 organisations implementing BIM. Problems the organisations have experienced because of the incompetence of external parties include: workload increment due to the re-work and need of inserting information into the models (Xu *et al.*, 2014); lack of integration of the different design disciplines in the models; delays in the completion of tasks; and lack of information in models:

> *"Simply if we give a Revit file and is given back to us in AutoCAD and we need to implement it here, that's a deficiency, that is backwardness in the delivery time, in the elaboration process. It takes valuable time from the employees"* – Interviewee 37, Org. 26.

Other minor difficulties these organisations have faced due to the lack of supply buy-in are Resistance to adopt BIM, identified by three organisations (Org. 12, 16, 18); and Resistance to sharing information; recognised by two organisations (Org. 12, 32).

5.4.2.3.2.2 Lack of BIM knowledge and involvement from clients

Client's involvement is fundamental during the implementation of BIM (CIC, 2011). Nonetheless, Interviewees from 3 organisations stated that clients had represented a hindrance for proper implementation of BIM because of their lack of BIM knowledge and involvement in the implementation. Interviewee 35 from Org. 24 pointed out that: *"clients don't give you time, time for the company to prepare, time for training",* inferring that clients do not understand the implementation process; therefore, they do not allow the organisation to invest the required time for the implementation. In contrast, Interviewee 32 from Org. 21 defends the position of clients when arguing: *"Engineers are on-site, projects have a deadline, clients have even more pressure for the delivery. Telling them: "Hey, let's do it slowly because we want to implement something", that's not going to happen for now".* She further says: "We cannot say to a client: *"We will do your project very slow because we want to implement BIM". The client will not understand this",* concluding that clients will not slow down their projects to consider the implementation of BIM simply because they do not see the value of it.

5.4.2.3.2.3 Lack of BIM skilled professionals in the country

Lastly, Interviewee 26 from Org. 12 commented that the organisation has slightly struggled to recruit BIM skilled people because of the shortage of BIM professionals in the country.

5.4.3 Organisations implementing BIM

In this section, more specific details regarding BIM in the organisations currently implementing BIM will be drawn to identify to get a better insight into their approaches.

5.4.3.1 Scope of the implementation

As explained in the classification criteria, organisations did not have to exclusively implement BIM across all their business processes to be part of this classification. Following the literature, the classification took into consideration the implementation of BIM in either a single discipline or a multidisciplinary approach or integrated into other processes of the organisations. As per Gu and London (2010), the scope of BIM implementation is flexible and can be adopted just in specific parts of the project lifecycle. They explain that the implementation of BIM can range from a complex fully integrated multidisciplinary BIM, where there is online collaboration, and every stage of the project can be updated in real-time; to a single disciplinary BIM implementation, where there are independent models for specific phases, sub-phases or tasks within a phase.

Similarly, Coates *et al.* (2010b) opined that an organisation could decide whether to implement BIM at a single or multidisciplinary manner taking into consideration that the main benefits can only be obtained through a multidisciplinary approach. However, there are contrary statements in that matter. Autodesk (2012) indicated that an effective BIM implementation must encompass all business processes. It should not be a simple IT or R&D initiative or executed only at a project or at a disciplinary level, which is known as "lonely BIM". Despite being beneficial, this type of approach does not entirely change business and just provide limited benefits. In that respect, Interviewee 32 from Org. 21 made an important statement*:*

> *"I am not doing BIM by only working with Revit as an Architect. I am just drawing in Revit […] Until the Cost estimator, the engineers of all the disciplines (Structural, Plumbing, Electrical) get involve… clients, suppliers, HAV, equipment... That is BIM. It is a whole. It is everything. It is an alive body, not a portion of it […] When all this myriad of actors gets involved in a project, get together, then it will be BIM."*

That infers that she does not consider they are implementing BIM because the approach so far is in one discipline only.

The organisations in this study classified as implementing BIM do not do it across all their businesses. Instead, they do it in specific disciplines and process, a limited approach still considered as valid by Gu and London (2010) and Coates *et al.* (2010b). Org. 18, 21, 24 and 26 implement BIM intra-organisationally and at a disciplinary level only in Architectural design, despite these organisations are also dedicated to construction. Org. 26 has gotten the opportunity to perform clash detection when the design of technical disciplines has been subcontracted. Org. 11 is also an organisation whose implementation of BIM is limited to Architecture in terms of design, but Interviewee 16 indicated that the use of BIM reaches the construction stage. Inter-organisationally, the organisation has had the opportunity to develop the Structural design in BIM once. Org. 12 is dedicated to Construction Management; therefore, they receive the design of different disciplines from external parties. For that, they demand Revit files, but when this is not possible, they have gotten involved in the task by converting files into Revit if they need to. That also denotes a platform approach rather than OpenBIM (Refer to Chapter 2, Section 2.2.3).

Interviewees 20, 21 and 23 stated that the implementation of BIM in the organisation is multi-disciplinary. However, Interviewee 26 commented that the implementation only covers the Architectural design in terms of design disciplines because the remainder design disciplines are inserted in the model rather than been conceived in a BIM workflow. BIM is also used for clash detection, construction programming and project control. Org. 17 implements BIM only for the design of the disciplines they are involved with (i.e. electrical and plumbing) which are all subcontracted, and for construction programming. This organisation also does construction supervision, but it was not indicated that BIM is used for this task. Org. 16 implements BIM for the design, modelling and detailing of Architecture, Structure and Plumbing. They also conduct clash detection in-house and supervise projects on-site. It is important to note that when a project is small, the organisation prefers not to implement BIM due to the extra costs it implies. Lastly, Organisation 32 is dedicated to the project's control. They use BIM for project management, clash detection and quantity take-off.

5.4.3.2 Reasons why the scope of BIM in the organisations is not broader

As previously explained, none of these organisations fully implement BIM within their practices. The reasons why the implementation of BIM is limited and has not surpassed other business processes in the organisations were indicated by the interviewees (Refer to Figure 5.3):

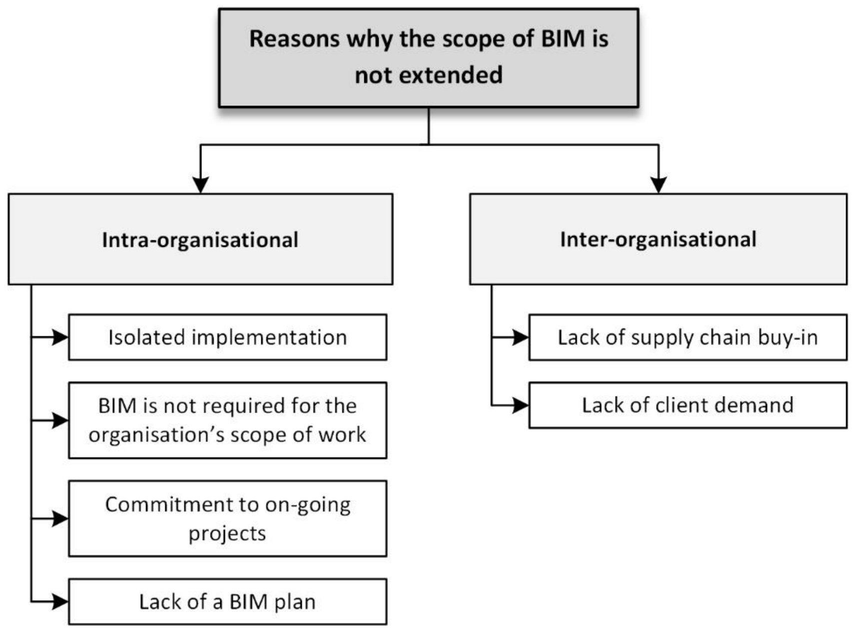


Figure 5.3 Reasons why the scope of BIM is not extended in organisations currently implementing BIM

5.4.3.2.1 Intra-organisational

Intra-organisational reasons identified by the interviewees as to why the scope of BIM is not extended in their organisations include Isolated implementation, BIM is not required for the organisation's scope of work, Commitment to on-going projects, and Lack of a BIM plan.

5.4.3.2.1.1 Isolated implementation

The implementation has not been fully realised in three organisations because it has been carried out in an isolated manner. In other words, the implementation has not included all the personnel from all disciplines. Interviewee 16 from Org. 11 stated that the Architectural staff has been more prepared for the implementation; therefore, there are some deficiencies in the Engineering disciplines that do not allow them to expand their scope. Interviewee 27 from Org. 17 explained: *"I do specific things; it is an isolated implementation. It is like BIM Level 1 where you do not collaborate"*, inferring that the organisation focuses on specific tasks, not in the whole implementation. Moreover, Interviewee 21 from Org. 12 argued that the implementation in the organisation has only involved some employees, not the entire personnel, but the knowledge they have acquired and the work they have done thus far has been useful. Apart from ineffective processes, isolated BIM initiatives to specific departments can lead to resistance towards change in other parts of the organisation (Vass and Gustavsson, 2017).

5.4.3.2.1.2 BIM is not required for the organisation's scope of work

Interviewee 27 from Org. 17 and Interviewee 37 from Org. 26 both stated that BIM is not entirely implemented within their practices because a complete implementation is not necessary. Interviewee 27 said that *"Because it is not economically viable for the organisation to acquire software if I am not executing activities that demand their purchase"*, inferring that the implementation is not absolute because the organisation does not have all the software required for that. He later added: "*I do not make the* *[software] investment because of the service I offer, and because clients do not demand a complete implementation either. If not, I'd do it. But if an opportunity comes up, I would acquire the software temporarily"* indicating that the decision does not only depends on the organisation's scope of work but also the client's demand. Interviewee 37 argued that: "*We are a Design, Construction and Real Estate company. Currently, I consider that BIM works perfectly until the scope we have set […] It is limited to Architecture. Obviously, it would be 100% and extremely efficient if all the Engineering disciplines be part of the process, but it is not like that […]*" indicating that BIM is only implemented in the speciality discipline of the organisation, Architecture, and recognising that including the other disciplines would be more advantageous but those disciplines are not part of the organisation. He further says: *"I consider that pure BIM works only for large companies, very efficient but with another scope. Maybe international companies take advantage of BIM",* reflecting that a complete BIM implementation can be realised only in large enterprises and the international market, not in the D.R. This is consistent with Ghaffarianhoseini *et al.* (2017) statement that any relevant BIM benefits are more likely to be spread in large organisations since they are the leading BIM adopters.

5.4.3.2.1.3 Commitment to on-going projects

The urgency of stakeholders to concentrate on on-going projects that are economically successful and need risk mitigation hinders the adoption of BIM in the industry (Singh and Holmström, 2015). Interviewee 32 from Org. 21 argued that they could not complete the implementation of BIM as desired because they have responsibilities in the organisation that cannot be ignored to implement BIM further. She pointed out different aspects such as time, profits of the organisation as well as the difficulty of the process.

5.4.3.2.1.4 Lack of a BIM plan

Interviewee 21 from Org. 12 opined that BIM is not fully implemented because the organisation has not prepared a proper plan for these purposes: *"If it is done and the resources are defined, it will be achievable. But a working plan has not been defined for the implementation of BIM in the company".*

5.4.3.2.2 Inter-organisational

Intra-organisational reasons identified by the interviewees as to why the scope of BIM is not extended in their organisations include Lack of supply chain buy-in and Lack of client demand.

5.4.3.2.2.1 Lack of supply chain buy-in

Lack of supply chain buy-in was considered as a significant deterrent to expanding the implementation of BIM in 5 organisations involved with the implementation. Interviewees stated they could implement BIM as much as they can in the design disciplines that are part of the organisations, but when external parties are involved, the continuation of the implementation is not in their hands: *"but the problem is that it is not implemented 100% because the Design of other disciplines besides the Architectural is not included"* – Interviewee 16, Org. 11.

Furthermore, Interviewee 23 discussed the difficulty of implementing IPD, the ideal project delivery for BIM implementation, when working with members of the supply chain because of the mistrust among professionals in the country:

> *"We haven't been able to implement IPD 100% because it is difficult in this country […] because in this country we still have the conception that people will trick you".*

5.4.3.2.2.2 Lack of client demand

Interviewee 35 from Org. 24 stated that the organisation does not go further with the implementation of BIM because clients do not demand BIM for their projects.

5.4.3.3 Standards adopted for the implementation of BIM

"Standards play an important role in ensuring the wider adoption of BIM technologies, processes and collaboration by ensuring that the same accurate data can be accessed throughout the supply chain"- Mark Bew, former chairman of the BIM Task Group (BSI, 2013). Due to the importance of adopting standards to ensure consistency in the implementation of BIM, interviewees were enquired about which BIM standards they follow in their practices.

Six out of the eight organisations use some standards to manage the implementation of BIM. Table 5.7 presents the organisations along with the standards and their use. It can be observed that the standards are mainly used for file and model management. There is also a significant influence of American Standards from AIA. In that respect, Int. 23 CEO of Org. 12 stated that "We follow standards from the USA in everything […]", illustrating the how much this organisation trusts the standards developed in this country. Also, Int. 20 from the same organisation opined *that "because this is the market we can get involved with, the closest we have. It is the one we have more similarities and contacts with. We have clients from the USA"*, inferring that this American influence is mainly due to the proximity of both countries and the likeliness to work with professionals and organisations in the USA. On the other hand, British standards are followed by Org. 17 (Uniclass) and Org. 12 uses PAS-1192-2 as a guide only.

Table 5.7 Standards used for the implementation of BIM in the organisations

Organisation	Standards	Purpose of their use
11	AIA*	Model creation guidance: LOD, Classifications.
12	AIA	Naming convention (for BIM models, AutoCAD files and 2D Documentation)
	UK (PAS-1192-2)	As guidance only
16	AIA	Elaboration of files, File saving, Naming conventions, Sheets formats, Parametric information, Presentation.
17	Uniclass (UK)	To name elements in the model
26	AIA	Naming conventions and BIM monitoring
32	AIA	LOD, Contracts, How Change of orders and RFI's are made

*Interviewees did not provide the name in specific

It was interesting to note contradictions among interviewees from Org. 12 concerning the use of BIM standards. For instance, Int. 20 and 23 from Org. 12 stated the organisation follows BIM standards from the AIA. However, Int. 26 said that the organisation does not follow any standards and even noted that this is not crucial for the implementation: *"I think our work dynamic is fine and I don't think we have a failure in this manner. Maybe we will create a manual later on*".

Moreover, Int. 21 did not know that there were standards for BIM, neither that the organisation was implementing any. That infers that the adoption of standards in this organisation is not spread throughout the organisation and has not been communicated to all the personnel either. Although this organisation is following BIM standards, Interviewee 23 said that they had created their protocol to name their files advised by their BIM trainer. Furthermore, Interviewee 45/H from Org. 32 explained that they follow standards and adapt them and create their own to have the same language within the organisation.

Interviewees from Org. 18 explained that they do not follow any standards and that the implementation in the organisation has been pragmatic. Furthermore, Int. 35 from Org. 24 stated that they work collaboratively without following any BIM standards. He explained the organisation produced a naming convention to name its projects.

Overall, there are two organisations that do not follow any standards and six organisations that adopt various BIM standards from other countries. The organisations that follow BIM standards have adopted standards from the USA and the UK, but they are applied to a limited extent. Moreover, it can be inferred that the non-adoption and adoption of various standards could affect the consistency of the data managed in a BIM project in these organisations, especially when working with external partners. Indeed, there is a need for more guidance regarding the importance and proper use of BIM standards in the country.

5.4.3.4 Benefits realised with current BIM implementation

Interviewees were also asked about the benefits they have obtained with the implementation thus far. The responses received were very diverse and grouped into five categories: *Benefits for the client*, *Design benefits*, *Construction benefits*, *Improved workflow* and *Organisation's profitability*.

5.4.3.4.1 Benefits for the owners/clients

Four interviewees from three organisations pointed out their clients have benefitted from the implementation of BIM because they have been able to 'offer a better service' and because the implementation has helped clients 'to understand the design' better.

5.4.3.4.2 Design benefits

Twelve interviewees from seven organisations reported to had obtained benefits in the design process and design results of their projects in the following aspects: enhanced visualisation, fast and accurate generation of project's information, automatic design corrections, faster design process, higher quality of work, improved coordination of disciplines, and easier development of structural designs.

5.4.3.4.3 Construction benefits

Three interviewees from three organisations stated they had obtained benefits in the construction process by avoiding mistakes before starting to build.

5.4.3.4.4 Improved workflow

Twelve interviewees from all the organisations that implement BIM mentioned benefits related to the internal improvement of their workflow after the implementation. 'Time savings' was particularly the main benefit identified in this category, reported by nine interviewees from six organisations. Nonetheless, it was also considered as a disadvantage in the implementation, as stated by Interviewee 35: "*But we don't always save time. When I apply technology, I don't save time. After I get skilled, I do […]"*, inferring that time savings are only realised after the person has learned how to work with the methodology.

5.4.3.4.5 Organisations' profitability

Seven Interviewees from six organisations pointed out economic benefits for the organisations, which allows them to be more profitable. Money savings was the most identified benefit of this nature, reported by six interviewees from five organisations. Interviewee 27 argued that BIM had helped the organisation to get 'more clients'. At the same time, Interviewee 25 form Org. 16 stated that BIM had given the organisation a competitive advantage, which helps the organisation to get more clients, more projects, and, therefore, is more profitable.

5.5 Summary

This chapter discussed the status of BIM in the Dominican construction industry. It started by presenting the level of BIM awareness among the participants of the construction organisations, from which 89% stated to be aware of BIM. Then, the participant organisations were classified according to their BIM involvement in organisations that do not implement BIM, organisations in transition to implementing BIM and organisations implementing BIM. Studying the organisations that do not implement BIM shed light into the reasons why BIM is not implemented in the organisations, as well as openness and drivers for future BIM implementation. The study of the organisations in transition to implementing BIM and implementing BIM illustrated the drivers for BIM implementation, BIM implementation strategies, and issues affecting their current involvement with BIM. By further studying the organisations implementing BIM, it was possible to verify the scope of implementation, standards used to manage the implementation of BIM as well as the benefits obtained from their current approaches. Table 5.8 presents a summary of the Chapter.

Table 5.8 Summary of Chapter 5

Organisations that do not implement BIM	
Reasons why BIM is not implemented	Intra-organisational reasons: - Lack of BIM knowledge - Resistance to change - BIM perceived as complex - "BIM is not suitable for our projects" Inter-organisational reasons: - Lack of supply chain buy-in
Openness to implementing BIM	- 73%: Yes - 14%: No - 12%: Uncertain
Potential drivers for BIM implementation	- BIM benefits - Competitive advantage
Organisations in transition to implementing BIM and implementing BIM	
Drivers for BIM implementation	- BIM benefits - Competitive advantage - Pressure from external partners
BIM implementation strategies	People: - Provision of training (focused on software) - New Personnel's roles

	Technology: - Change/Upgrade hardware
Issues affecting their current involvement	Intra-organisational: - Combination of 2D and 3D software - Unorganised implementation - Inadequate information management Inter-organisational: - Lack of supply chain buy-in - Lack of BIM knowledge and involvement from clients. - Lack of BIM skilled professionals in the country
Organisations implementing BIM	
Reasons why the scope of BIM is not extended	Intra-organisational: - Isolated implementation - BIM is not necessary for the organisation's scope of work - Commitment to on-going projects - Lack of a BIM plan Inter-organisational - Lack of supply chain-buy in - Lack of client demand
Standards adopted to manage the implementation	- For file and model management - Mainly American standards (AIA)
Benefits realised with current BIM implementation	- Benefits for the owner/clients - Design benefits - Construction benefits - Improved workflow - Organisations' profitability

The next chapter (i.e. Chapter 6) discusses the findings regarding BIM Education in the country.

CHAPTER 6: BIM EDUCATION IN THE DOMINICAN REPUBLIC

6.1 Introduction

Education is a process that involves activities to construct knowledge such as teaching, inducing, motivating, learning, examining and is usually provided in schools and colleges (Oladosu, 2009). Education requires a learning method, which must include understanding and cannot be an individual event (Garavan, 1997). On the other hand, training is one of the processes part of Education (Peters, 2010). As per Oladosu (2009), training comprehends the acquisition of skills in a specific field of specialisation, which demands an exercising routine, iterative processes, and a clear intention. Training is an activity commonly provided in organisations. In this context, it is knowns as "employee training", which means obtaining on-the job-skills for a specific role (Masadeh, 2012).

Table 6.1 Differences between education and training

Source: Oladosu (2009) and Masadeh (2012)

Education	Training
Broad scope	Limited field
Knowledge development	Specific skills
Theoretical method	Practical method
Stricter background	Hands-on experience
Mostly given in schools and higher education	Usually given on jobs

Both processes correlate and involve learning process, yet differ significantly. Table 6.1 summarises relevant differences between each process which are regarding the scope, depth of the knowledge sought, and the learning method applied for its acquisition.

After understanding and identifying the differences between both terms, BIM education has been defined as "*a continuous learning process that covers the knowledge required for individuals to be capable of being part and understand what a BIM process is. Such learning process needs to include the essential aspects of BIM implementation, the performance of the participants and the technical skills individuals need to acquire depending on the discipline they belong to and their role in the construction team"* (Silverio *et al.,* 2016; 2017a).

This chapter discusses the results of the study of BIM education in the country to achieve the fourth objective of this study which is "*To explore and document the presence of BIM Education in the country"*. The chapter presents the investigation process on the subject, discusses the key findings on the current status of BIM Education in the country and, lastly, draws conclusions based on the key findings presented.

6.2 Investigation process

The first manifestations of BIM education in the country were identified in the preliminary study. First, a training centre (Training Centre A) that delivers a kind of "BIM seminar" in the last phase of a software training course in Vectorworks was identified. Also, an interviewee talked about the interest of one university (University B) of integrating BIM in the Civil Engineering curriculum.

Findings from the literature and the preliminary study suggested the inclusion of the topic of BIM Education in the country, which corresponds to the fourth objective of this study. To achieve this, an investigation was carried out to explore BIM education in the country and look for potential candidates that could be interviewed in the main study. The investigation consisted of an online search using keywords (in Spanish) related to BIM education and training. As presented in Table 6.2, the findings were mostly training related. There were found two diploma courses, a conference, BIM software courses for Architecture Design and an Architect dedicated to the dissemination of BIM knowledge. Furthermore, websites of universities that offer careers in the field of construction were searched, and keywords were also used in the professional networking LinkedIn; however, no new results emerged.

Table 6.2 Results of the online search on BIM education in the D.R.

Keywords combination	Results
BIM + Educacion + Republica + Dominicana	BIM diploma course and BIM informative seminar in *University A*
	A conference dedicated to BIM and IPD in *University B*
BIM + Diplomado + Republica + Dominicana	BIM diploma course in *University B*
	Three Revit courses and one ArchiCAD course
BIM + Cursos + Republica + Dominicana	Webpage of an Architect dedicated to the dissemination of BIM knowledge
BIM + Universidad + Republica + Dominicana; BIM + Formacion + Republica + Dominicana	No results

A lecturer from University A (Interviewee C) and the previously mentioned Architect (Interviewee G) could be contacted through the online search. Furthermore, the investigation identified a professional body (Professional Body A) that hosted a BIM seminar delivered by Interviewee G, which is available online. A representative from Professional Body A, Interviewee E, was reached through the researcher's professional networking; whereas the rest of the participants were sampled through the snowball sampling strategy.

In total, nine people participated in the study of BIM Education in the country. The profile of the participants is described in Table 6.3. The subsequent sections present the key findings of this investigation.

Table 6.3 Profile of the participants of the study of BIM Education in the country

Interviewee	Profile
A	Civil Engineer and MSc in BIM.
B	Non-graduate. He was a student of Architecture.
C	Civil Engineer. Professor and Researcher at *University A*.
D	Architect. Founder member of *Training Centre C*.
E	Architect. Director of the Continuing Education Department of the Headquarters of *Professional Body A*.
F	Architect. Professor at *University C*, CEO of *Training Centre A,* and exclusive Vectorworks provider
G	Freelance Architect.
H	Civil Engineer. Professor at *University A.*
I	Architect.

6.3 Shortage of BIM experts

Due to the novelty of BIM and current development within the construction industry, only a small group of educators are committed to spreading BIM knowledge across the industry (Gardner *et al.*, 2014). Hence, it was expected to find the same situation in the Dominican Republic, a country with limited indications of BIM implementation. The shortage of BIM experts was first confirmed during the search of people related to BIM education in the country. Furthermore, only six out of the nine participants in the study can be considered BIM experts. The three remainder interviewees (Interviewees C, D and E) are just supporters of the dissemination of BIM knowledge and do not deliver any BIM knowledge themselves (Refer to Table 6.4).

Table 6.4 Academic background of the participants and BIM training/knowledge they provide

Int.	Academic background on BIM	Modes of providing BIM knowledge and training
19/A	BIM diploma course at University A MSc in BIM in the UK	Coordination of the BIM diploma course in University A; Seminars.
B	No education. An autodidact with books and the internet.	Seminars; Revit courses oriented to BIM; Revit in-house training and BIM champion of the company he works (Org. 16).
C	BIM diploma course in University A. Does not teach about BIM; he is just a supporter.	Coordination of the BIM diploma course and seminars in University A; Coordination of the insertion of two BIM modules in the Civil Engineering curriculum of University A.
D	No education. Just software courses in Revit. Does not teach about BIM; he is just a supporter.	Development of conferences where BIM seminars and panels have been included; Coordination of Revit courses oriented to BIM.
E	No education. Does not teach about BIM; he is just a supporter.	Host seminars; Interest in delivering courses on BIM.
F	No education. An autodidact with books and the internet.	Seminars; Vectorworks courses oriented to BIM; Software consultancy to companies.
G	No education. An autodidact with the internet.	Revit courses oriented to BIM; BIM diploma courses; Revit in-house training and BIM implementation strategies consultancy to companies; Seminars.
45/H and 46/I	BIM diploma course at University A.	Coordination of the BIM diploma course in University A; BIM diploma courses; Participation and organisation of seminars, conferences and forums in University A and Training Centre D; Training and consultancy to companies; Revit training courses oriented to BIM.

6.4 Lack of BIM education: Presence of training only

Hitherto, BIM education is not provided in Academia. There is only presence of BIM training focused on software skills. Training is delivered in the form of software courses and diploma courses. Construction firms are demanding in-house software training and consultancies to implement BIM in their practices. Moreover, BIM knowledge is currently being disseminated in the country through educational activities and a BIM informative forum.

The lack of BIM education in the country has been a hindrance not only for the implementation of BIM in the Dominican construction industry but also for the stakeholders involved in the delivery of BIM training/knowledge. As presented in Table 6.4, many of the interviewees are autodidacts in the subject of BIM. Only interviewees 19/A, C, 45/H and 46/I, took a BIM diploma course in the country that is not delivered permanently in the country. Also, Interviewee 19/A got a master's degree in BIM from overseas.

6.4.1 Software courses

Software courses are the most common type of BIM training delivered nationwide; however, the majority do not tend to focus on BIM implementation. In their description, most of them do not even mention the word BIM and, when they do, it is basically to point out they teach a BIM software. This issue was also reported by several interviewees (19/A, B, G, 45/H and 46/I), who criticised training centres that deliver software courses not only for their lack of BIM emphasis but also for their incompetent teaching approaches:

> *'That's the other issue, that the courses delivered in this country are normally focused on software and the trainers, I won't say all of them, but some of them are software providers, and they restrict themselves to teach you the software. They do not give you the vision of implementing BIM in a project"* – Interviewee 19/A.

Contrary to this trend, several of the interviewees (*B, F, G, H and I*) that provide BIM software courses reported that they do focus on teaching BIM:

> "*I explained to them BIM with Revit as follows: Revit has different wall types [...] These walls have a definition that is called LOD in BIM [...] "For you to do a LOD 100, you need a simple basic wall", "For a LOD 400, you need a basic compound wall and is done this way. And because this wall has a LOD 400, it allows you to do construction programming and cost estimation". So, in this way, I do both, I teach Revit and BIM [...]"* - Interviewee G.

6.4.2 BIM diploma courses

BIM diploma courses were the most formal type of training identified. These courses are not regularly provided and tend to focus on software skills, more specifically in Autodesk software. When the investigation of BIM Education was conducted, there were only found two diploma courses delivered in 2013. The first one was delivered at

University A, a recognised University that only offers the course of Civil Engineering. The second one took place at University B, another prestigious university that delivers undergraduate courses in Civil Engineering, Architecture and Interior Design.

6.4.2.1 BIM diploma course at University A

The diploma course was organised by the staff of this university (including interviewees A, C, H and I) along with Professors from Brigham University (USA), who were the facilitators. The course was conceived from an agreement between both universities. As per Interviewee C, the course mainly covered an introduction to BIM, modelling in Revit, and the use of Navisworks for programming and clash detection.

6.4.2.2 BIM diploma course at University B

Even though the facilitator of this diploma course could not be contacted for the study, some details of the course could be extracted from the internet. The objectives of the diploma course included the identification and definition of IPD and BIM processes; the use the software Revit and Navisworks and their implementation in BIM and IPD; and the development of a BIM project.

6.4.2.3 Growth of BIM diploma courses

During and after the interviews were conducted, other diploma courses were identified. During the interview, Interviewee G stated to have designed a BIM Diploma course to teach BIM along with the software Revit. The course was projected to be delivered at the beginning of January 2017 in two universities in the capital and North of the country. It is important to point out that this course has been continuously delivered ever since. Furthermore, after the interviews were conducted, Interviewees 45/H and 46/I published a BIM diploma course in Training Centre D. The course had three modules: Introduction to BIM, Project's coordination with BIM and Implementation of BIM; and it required students to be Revit skilled. These findings indicate that the delivery of this type of training is growing in the country.

6.4.3 In-house training and BIM consultancy to companies

Several interviewees have been demanded the provision of these services, which infers that construction organisations are getting interested in BIM. Interviewee B is driving the implementation of BIM as the BIM champion in Org. 26 (Refer to Chapter 5, Sections 5.4.2.2.2 and 5.4.2.2.3). Interviewee E has delivered software consultancy to companies through the Training Centre A. Interviewee G has driven the implementation of BIM in some companies. He also provides in-house training in the software Revit, service that he has even delivered abroad. Interviewees 45/H and 46/I have given consultancies in BIM implementation strategies to companies and in-house training in the software Revit and Navisworks.

6.5 Dissemination of BIM knowledge in the country

As per Mordue *et al.* (2015), events and gatherings are excellent places where people can network with colleagues, unite forces and share ideas. Networking in this type of activities is very significant and allow people interested in BIM to meet frequently to talk about topics and the improvement of BIM in the industry. In the Dominican Republic were identified BIM-related educational events such as seminars, conferences, and forums. As indicated in Table 6.4, all the interviewees have been involved in this type of activities as facilitators or organisers. These activities have been mainly hosted in universities throughout the country, followed by professional bodies, and training centres. The popularity of these activities is increasing lately.

Mordue *et al.* (2015) also indicated that associations and forums are places where people unite their forces (either in person or virtually) to share ideas, thoughts, and point of views on specific issues usually through sub-committees or specialist group interest fields. This mode of sharing knowledge also exists in the country. In December 2016 was created the first informative BIM forum of the country called ProBIM, initially led by five professionals of the construction industry, including the researcher. The forum started with an interactive web page to share short articles of basic concepts about BIM, news, and information about local and international BIM events, and places where people can seek for BIM education/training. Nowadays, the forum is just present in social media platforms: Instagram (user: @ProBIM_ORG), LinkedIn and YouTube (user: ProBIM), where Instagram is the most important channel. Short articles are published through Instagram about different topics: general BIM knowledge, emerging tendencies, case studies of BIM projects, etc. Also, live videos are broadcasted to cover specific and trendy topics. Both, the publications and videos are shared in the other platforms (ProBIM, 2016; ProBIM, 2017; ProBIM, 2019a). The forum has contributed significantly to the diffusion of BIM knowledge among professionals of the industry. It has also grown in terms of members and scope. In the last two years, it has hosted educational activities in different universities and in Professional Body A to raise BIM awareness in the industry. Lastly, the forum is committed to driving the OpenBIM approach in the Dominican construction industry. Proof of that is their latest event "2da Jornada OPEN BIM" (2nd OPEN BIM Conference, in English), which was around this topic (ProBIM, 2019b).

The interest in disseminating BIM knowledge in the country has also come from professional bodies. The Professional Body A has hosted activities where BIM knowledge have been disseminated: an introductory BIM seminar conducted by Interviewee G; and seminars held by Interviewee 45/H and 46/I where the topic of BIM has been included. Moreover, Interviewee E confirmed that the institution is interested in offering BIM courses. There was already one attempt of delivering a BIM diploma course from the institution, and they currently want capable facilitators for this purpose. After the interview, they have worked along with ProBIM and organised a BIM seminar that had a high reception in the construction industry.

6.6 Plans on BIM education and training

Interviewees were asked about their plans concerning the provision of BIM knowledge and BIM education and training. Most of them stated that they will continue with their work and want to expand and explore further areas. Their plans include the creation of BIM diploma courses (Interviewees 19/A, B and D); propose the delivery of BIM diploma courses in Professional Body A, mainly in the countryside (Interviewees 45/H and 46/I); delivery of multidisciplinary software training (Interviewee D); Navisworks software courses (Interviewees A and D), and host more BIM events and deliver BIM courses in the Professional Body A (Interviewee E).

Some interviewees shared other ambitious plans not related to BIM education per se. Interviewee 19/A wants to create BIM groups, do research about BIM and elaborate documents such as BIM standards for the country. In the same manner, Interviewee G intends to create a BIM standard with the group of students and colleagues he has gathered on his labour as an educator. Also, Interviewee 45/H and 46/I plan to propose the implementation of BIM in governmental institutions.

Undoubtedly, the most interesting finding was the ascertainment of a university plan to integrate BIM within a career's curriculum. As per interviewees A and C, there was a curriculum reform in the career of Civil Engineering in University A which will take effect for students enrolled from August 2016 onwards. The modifications encompass the improvement of one module and the insertion of a new module, both to be delivered in the last year of the career. The career is three years long; therefore, the new curriculum will be effective from 2019. The modified module is called "Technical drawing for Civil Engineering" and students will be taught the software Revit instead of the traditional AutoCAD. On the other hand, the new module is called "Computer-Aided Design" which is planned to be delivered by Interviewee 19/A. The content is still under development; however, Interviewee 19/A gave some details, including the intentions of teaching students the software Navisworks. The aim of both modules is that students acquire the necessary skills to use models for different tasks such as design analysis, clash detections, cost Estimations, construction schedules, construction simulations, etc.

Alike the BIM training approaches found in the country; this strategy is also focused on teaching specific software. Rooney (2017) identified this problem in the BIM education of several countries across the world: Australia, Singapore, Sweden, the UK and the USA. Education about openBIM concepts, BIM management, and BIM collaborative environments is increasing but has a long way to go in most of the countries.

It is important to note that the university is already introducing BIM to the students through a lecture called "Introduction to BIM" in the module "Construction administration" for last-year Civil Engineering students. The lecture is purely conceptual and covers topics such as tools used in a BIM process, benefits, case studies of projects that have implemented BIM successfully, papers, etc. Interviewee C indicated that the lecture has been successful as it has arisen awareness and interest in BIM among the students.

6.7 Summary

This chapter has discussed the presence of BIM education in the country. There are relevant initiatives related to BIM training and BIM education. A few professionals are making an effort to build BIM capacity in the construction industry. Nonetheless, the shortage of BIM experts is evident and suggests the availability of BIM education and proper BIM training in the country.

Thus far, there is only BIM training in the country which mainly focuses on teaching software. Current BIM training is prone to expand as BIM training providers are keen to continue with their work and explore new areas for teaching. Furthermore, the participation of professional bodies and the creation of the BIM informative forum are positive indicators that BIM awareness, the demand of BIM education and, therefore, implementation of BIM in the country is likely to increase in the country.

The interest in BIM is rising in Academia. Several universities across the country are hosting educational events to raise BIM awareness. Also, BIM diploma courses have been mainly delivered in universities. International collaboration has contributed significantly in that manner as one of the first diploma courses in the country was developed and delivered in alliance with an American University.

The most salient advancement identified was the plan of integrating BIM into a University curriculum. Such integration is planned to be in complementary modules and focused on BIM software. Although it is not the ideal approach, this has been the starting point of integrating BIM in university curricula in many BIM leaders' countries and can be improved with time.

These findings infer the need for guidance for the successful integration of BIM in university curricula. A framework to guide the integration of BIM in university curricula has been developed as part of the outcome of this research. Details of its development are discussed in Chapter 8 (Section 8.4.1).

The next chapter (i.e. Chapter 7) discusses the findings from the main study regarding the challenges of implementing BIM in the Dominican construction industry.

CHAPTER 7: CHALLENGES HINDERING THE IMPLEMENTATION OF BIM IN THE DOMINICAN CONSTRUCTION INDUSTRY

7.1 Introduction

This chapter presents the results from the main study on the challenges hindering the implementation of BIM in the Dominican construction industry.

In response to the question *"Which challenges do you think hinder the implementation of BIM at a national level?",* interviewees from the main study talked about the challenges they believe hinder the implementation of BIM in the D.R. Their responses were based on their outlook as professionals within their organisations and members of the Dominican construction industry. A myriad of challenges was identified by the interviewees, which were then categorised as part of the method of content analysis into the following categories: Inter-organisational/Environmental, Educational, Economic, Cultural and Standardisation challenges.

Furthermore, interviewees proposed initiatives that could help to propel the implementation of BIM in the country. These initiatives were categorised into the following categories: Provision of BIM Education, Government leadership and BIM diffusion in the industry.

The next sections will present the diverse challenges identified by the interviewees in detail, followed by the proposed strategies to propel the implementation of BIM in the country.

7.2 Inter-organisational/Environmental challenges

Inter-organisational/environmental challenges were identified by 29 interviewees from 21 organisations and BIM Education interviews. They include Lack of government support and Lack of client demand (Refer to Figure 7.1).

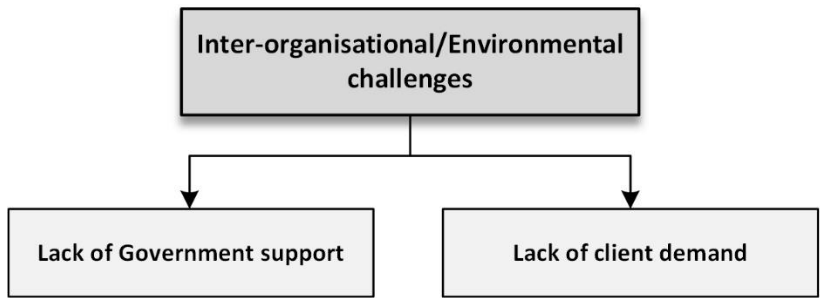


Figure 7.1 Inter-organisational/Environmental challenges to BIM implementation in the D.R.

7.2.1 Lack of government support

The involvement of the government is fundamental for the implementation of BIM; if not, the implementation of BIM will be slow and inactive (Zahrizan *et al.* 2013b). Lack of government support appears to be a pivotal challenge to BIM implementation in small markets or the denominated "developing countries". For instance, the lack of policies and legislation from the government have been reported in Nigeria, (Abubakar *et al.*, 2014), India (Sreelakshimi *et al.*, 2017) and Palestina (Enshassi *et al.*, 2016). Furthermore, the lack of support and motivation from the government have been identified in Iran (Hosseini *et al.*, 2015) and Jordan (Zahrizan *et al.* 2013a). Mahamadu *et al.* (2017) further stated that lack of promotion of standardised protocols, guidelines and any other means of implementation support hinders successful adoption.

Twenty-two interviewees from 17 organisations and the BIM education interviews stated that the lack of government support is a critical challenge to BIM adoption in the Dominican Republic. Furthermore, interviewees expressed to have low expectations on the government getting involved in the implementation of BIM. Their comments *'the government is corruptive'*, *'the government is unorganised'*, *'more time is needed for the government to demand BIM'*, *'they do not know about BIM'*, *'they only use 2D documentation'* further explain the point.

7.2.2 Lack of client demand

Lack of client demand is a common reason as to why many firms do not invest and make the transition to BIM (Eadie *et al.*, 2013a; Smith, 2014c). In particular, clients of small organisations do not make such type of demands and the smaller they are, the less likely this will happen (Lymath, 2014). Lack of understanding by clients about BIM requirements also represents a hindrance to proper implementation (Mahamadu *et al.*, 2017).

Sixteen interviewees from 16 organisations and the interviews on BIM Education stated that lack of BIM demand and interest from clients is another critical challenge to BIM implementation in the country. As per Enshassi *et al.* (2016), lack of BIM demand and interest from clients may be a consequence of lack of BIM knowledge or incertitude about the tangible benefits of BIM, which was a reason pointed out by 2 of the interviewees: *"…You are offering something new, and you need to demonstrate him/her (the client) why is beneficial for him/her […] The biggest challenge is to make people* *understand and see this necessity. It takes time for them to start demanding BIM […]* – Interviewee 34, Org. 23.

7.3 Educational challenges

The uptake of BIM also brings new challenges such as emerging knowledge and a skill gap among professionals of the industry (Mihindu and Arayici, 2008). Lack of BIM skilled professionals is a significant barrier to BIM implementation (Eadie *et al.*, 2013a; Lee and Hollar, 2013; Wu and Issa, 2013; Gardner *et al.*, 2014). Additionally, Arayici *et al.* (2011b) pointed out that training people or searching for people that know BIM is also a difficulty in the process of its implementation. Other education challenges include lack of skills and experience (Ghaffarianhoseini *et al.*, 2017), lack of expertise within project teams and organisations (Eadie *et al.*, 2013a), and learning curve of BIM (Azhar *et al.*, 2012; Zahrizan *et al.* 2013b). In the implementation process, inadequate project experience, lack of software skills and lack of BIM knowledge on how to work with BIM can result in productivity loss and projects' delays (Czmoch and Pękala, 2014; Ghaffarianhoseini *et al.*, 2017).

Twenty-seven interviewees from 16 organisations and the BIM Education interviews identified educational challenges to BIM implementation. These challenges were related to the Lack of BIM education in the country and the Deficiencies of the Dominican education system (Refer to Figure 7.2).

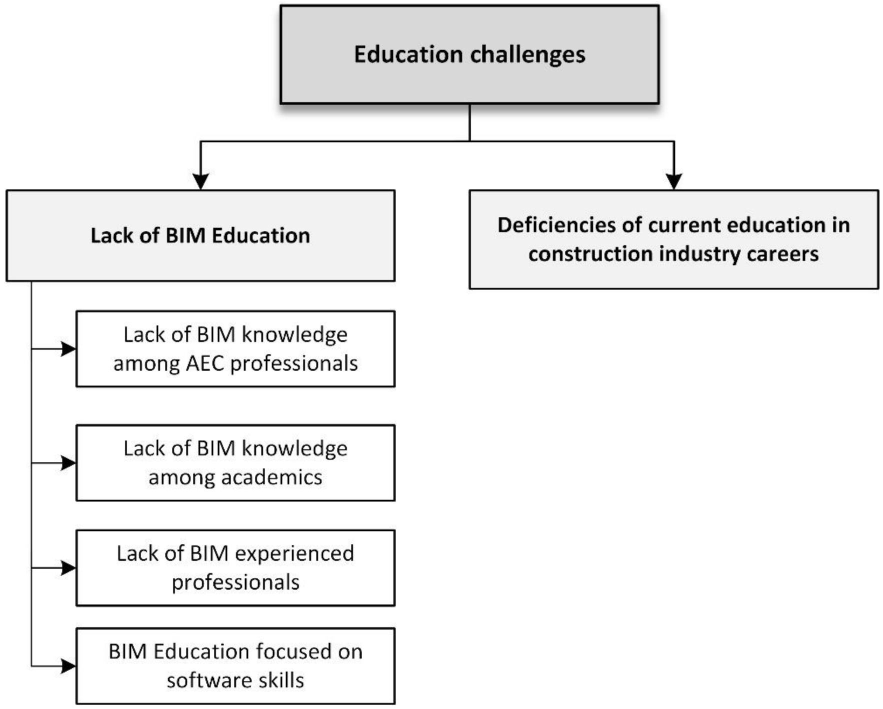


Figure 7.2 Education challenges to BIM implementation in the D.R.

7.3.1 Lack of BIM Education

As stated in Chapter 6, BIM education is not provided in the Dominican higher education. To date, there is only BIM training available focused on software, but there are plans to insert BIM with complementary subjects in a Civil Engineering curriculum by 2019 (Silverio *et al.*, 2017b). Fourteen interviewees reported the challenge of Lack of BIM Education:

> *"That is why I mentioned education in the first place. If you do not educate people about BIM, they won't invest anything because the investment is high. If they don't understand the importance of BIM, why would they invest in it? They would rather stay doing what they have*

> *been doing for all these years, which gives them profits."* - Interviewee 25, Org. 16.

Various challenges which are caused by the lack of BIM Education in the country also arose from the interviewees' responses. Six interviewees talked about the *Lack of BIM knowledge among professionals in the industry*. This comment further illustrates this issue:

> "*The problem here is the lack of awareness from people in general: government, companies, the professionals… because some people here may have an idea of what it is, but not all of them understand it or know which the benefits of using BIM are".* – Interviewee 32, Org. 20.

Two interviewees identified the challenge of *Lack of BIM knowledge among academics*. They considered that Dominican universities had not integrated BIM into their curricula because current lecturers in construction careers in the country may not know about BIM or neither have studied it. This challenge has been reported in several studies (Becerik-Gerber *et al.*, 2011; Gardner *et al.*, 2014; Kugbeadjor *et al.*, 2015; Rooney, 2015; Abbas, Din and Farooqui, 2016). Lack of experienced academics hinders the accomplishment of higher levels of BIM education and the availability of graduates with the necessary BIM collaborative competencies for the future of the industry (Rooney, 2015).

Two interviewees also recognised the challenges of *Lack of BIM experienced professionals*. As stated in the literature, lack of BIM experienced professionals represents a challenge to the universal use of collaborative working processes in the construction industry (Macdonald, 2012), for the implementation and technology in the industry (Becerik-Gerber *et al.*, 2011) and the adoption of BIM (Aouad *et al.*, 2006).

It has been reported that BIM education is usually taught focusing on the use of BIM software (Wong *et al.*, 2011a; Lee and Hollar, 2013; Abbas, Din and Farooqui, 2016; Rooney, 2017). In this regard, one interviewee pointed out the *BIM education focused on software skills* as a challenge to BIM implementation in the country. According to Interviewee 19/A, most of the higher education institutions and technical courses in the country focus on teaching software to the students, which affects their learning as they do not see the implementation of BIM as a process.

7.3.2 Deficiencies of current Education delivered in careers related to the construction industry

Six interviewees stated that the current higher education system of the country is deficient in preparing students in BIM. According to them, the deficiencies range from traditional curricula, fragmentation of the careers, lack of integration of the modules, and inefficient teaching in aspects such as communication and collaborative practices, the process of construction, finance and project's specifications.

Issues such as the fragmentation of the careers and the lack of integration of modules are not only present in the D.R. Historically, it has been reported that the education system of the construction industry has struggled to attain an effective interaction between disciplines (Kent and Becerik-Gerber, 2010).

7.4 Economic challenges

The cost of implementing BIM is usually perceived as a barrier for its adoption (Liu *et al.* 2015; Azhar, 2011). For effective implementation of BIM, construction companies need to make a substantial investment that includes investment in software, hardware, and training. BIM also implies some process investments such as the development of internal collaborative BIM processes and business investments for cultivating future BIM competencies (Ghaffarianhoseini *et al.*, 2017). The impact of the investment required for BIM implementation will vary according to the economic situation of the organisation (Eadie *et al.*, 2014). The high cost of implementation is what hinders small and medium organisations the most (Czmoch and Pękala, 2014), especially the initial costs (Bryde *et al.*, 2013; Eadie *et al.*, 2013a). Therefore, it is believed that the increment of BIM adoption is principally in large firms which have the financial resources for that purpose (Liu *et al.*, 2015).

Twenty-five interviewees from 16 out of the 25 organisations of the main study and the BIM education interviews identified several challenges that were classified under the category Economic challenges. They comprehend economic challenges intrinsic to BIM and related to the organisation (Refer to Figure 7.3).

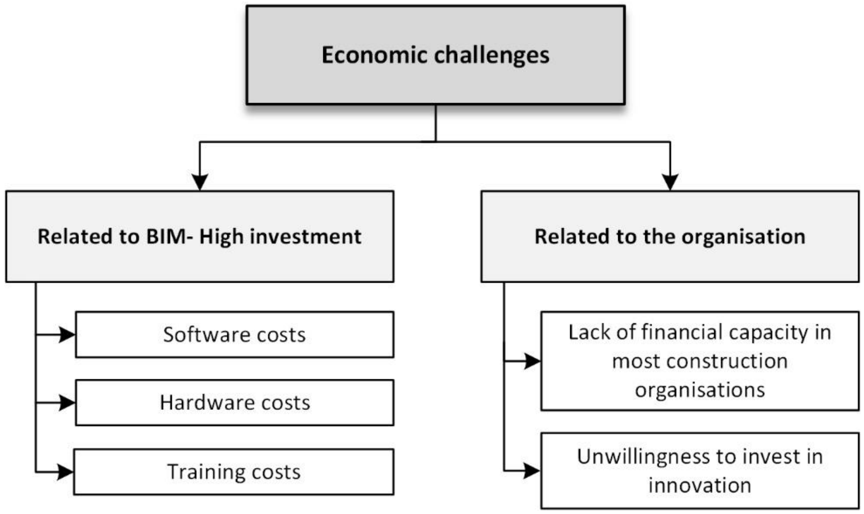


Figure 7.3 Economic challenges to BIM implementation in the D.R.

7.4.1 Economic challenges related to high investment in BIM

Twenty-five interviewees from 14 organisations and the interviews on BIM education reported that the high investment that BIM requires is an important challenge for construction firms in the Dominican Republic. Interviewees made comments related to specific investments: software costs, hardware costs and training costs.

7.4.1.1 Software costs

Nineteen interviewees from 12 organisations and the interviews on BIM education considered software costs as an important challenge to BIM implementation. It was interesting to note that, when talking about software costs, seven interviewees emphasised the problem of software piracy in the country. In this regard, Bui *et al.* (2016) stated that software piracy is an issue that is highly present in the commonly named "developing countries". Software piracy can affect the security of the organisations as they are inadvertently open to viruses and hackers' attacks that could cause unforeseen disturbances and uncontrollable damages. Two interviewees particularly indicated that software piracy is practised in the country due to the low professional fees of the industry, especially in the field of Architecture:

> *The reality is that any Architect of an average salary cannot pay licenses […] It is very difficult"* – Interviewee J.

7.4.1.2 Hardware costs

Ten interviewees from 6 organisations pointed out that the hardware needed for BIM represents a high investment for construction organisations. Interviewee 25 from Org. 26 argued:

> *"There needs to be a high investment in hardware too. Because we use models, we need powerful computers and devices; preferably computers rather than laptops […] On-site you can have a computer, but Engineers are always moving around, and you need to provide them with portable devices, which can be laptops or tablets. This investment in hardware is very high, in powerful hardware to implement BIM."*

7.4.1.3 Training costs

Lastly, seven interviewees from 6 organisations mentioned the investment required to train personnel in BIM. Three interviewees particularly pointed out the intrinsic risk of investing in training to employees who might leave the organisation afterwards. Interviewee 36 from Org. 25 argued: "*the training you need to provide to the personnel* *is expensive, the devices they need to use are expensive, and there is the risk of them leaving the company when they are skilled"*.

7.4.2 Economic challenges related to the organisations

7.4.2.1 Lack of financial capacity

Four interviewees added that many construction organisations in the country might not have the financial capacity to assume all this investment. Two of them explicitly stated that this investment is even more challenging for SMEs (Small and Medium Enterprises) (Bryde *et al.* 2013; Eadie *et al.*, 2013a; Czmoch and Pękala, 2014). Considering the average size of the construction organisations in the D.R., which is micro-enterprises, it can be inferred that a high percentage of Dominican construction organisations may struggle with this type of investment.

7.4.2.2 Unwillingness to invest in innovation

Investing in unknown technology implies uncertainties such as a higher anticipated cost and, therefore, risk. That is particularly accurate in situations where higher investment is needed regarding customers who are more resistant to use BIM (Xu *et al.*, 2014). Despite professionals knowing the benefits of BIM, there is lack of knowledge specifically on the economic impact and profits of BIM, and there is not a thorough list where BIM advantages are linked with costs savings (Mehran, 2016). These aspects can significantly discourage professionals from adopting and investing in BIM. Six interviewees reported that there is an unwillingness to invest not only in BIM but in technology in general in the Dominican construction industry. As indicated in the literature, the reasons identified were related to resistance to change, lack of knowledge on BIM economic benefits and the "typical" lack of interest in technology investment in the Dominican construction industry, which can also be considered as a cultural challenge. Interviewee 20 from Org. 12 argued: "*It is a general knowledge that Dominicans do not like to invest in new technologies until they are pushed because of necessity"*.

7.5 Cultural challenges

Culture is defined as "a set of mores, values, attitudes, beliefs, and meanings that are shared by the members of a group or organisation" (Williams A., Dobson P. *et al.* 1993). In the context of the construction sector, culture relates to the characteristics of the industry, construction methods, skills of craftsmen and people that work within the industry, and the goals, morals, approaches of the organisations they belong to (Abeysekera, 2002). National culture, management style, customs, etc. can affect the way of performing business. The business models and processes part of BIM illustrate European and U.S. industry practices; hence, there may be more resistance to adopt BIM in other areas of the world where different types of business models are implemented in the construction industry (Chan, 2014).

Twenty-three interviewees from 14 organisations and the BIM education interviews identified cultural challenges to BIM implementation in the D.R. (Refer to Figure 7.4). Interviewees noted challenges related to the characteristics and way of working of the Dominican construction industry, and attitudes towards BIM.

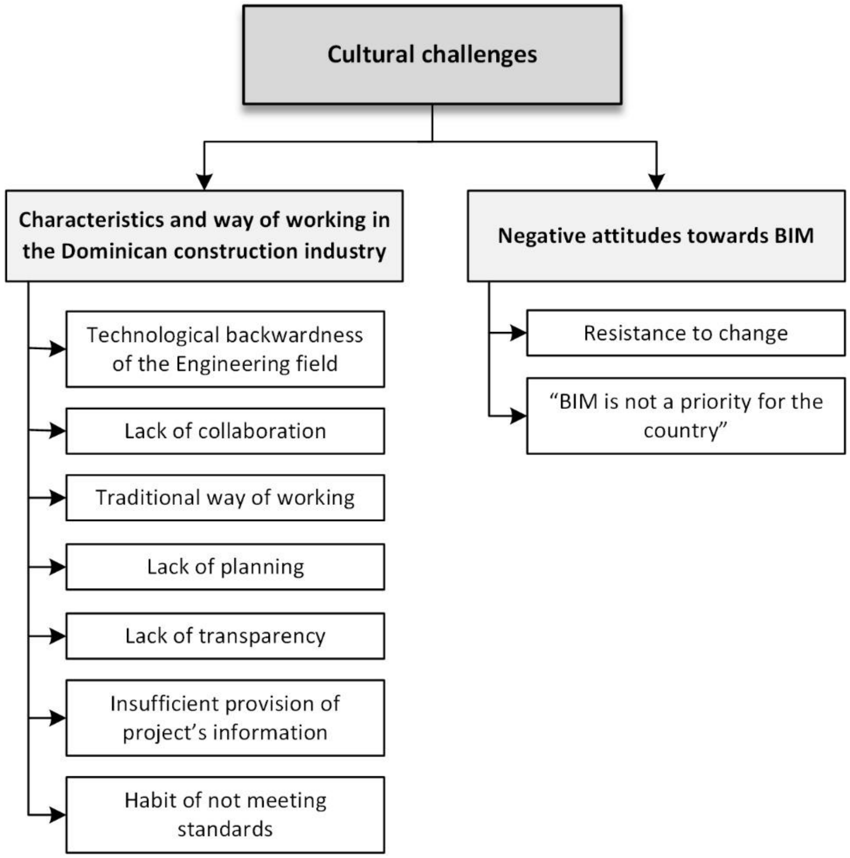


Figure 7.4 Cultural challenges to BIM implementation in the D.R.

7.5.1 Characteristics and way of working in the Dominican construction industry

7.5.1.1 Technological backwardness in the field of Engineering

Twelve interviewees stated that the Engineering field in the country represents a challenge to BIM implementation, mainly due to their lack of involvement and interest in technological advancements. Seven interviewees stated that the Engineering field in the Dominican construction industry tends to be undeveloped in terms of technology, which makes more difficult to spread the implementation of BIM throughout the industry: *"The problem is that Engineers, contrary to Architects, are not prone to be* *updated in technology. You can still find people that do an Electrical design with sketches"* – Interviewee G.

Furthermore, four interviewees were more specific by stating that there is a lack of interest in BIM in this field. Interviewee D pointed out that the involvement of BIM in Architecture has been more significant than in the Engineering field. On the other hand, Interviewee 53 defended not only Architecture but also Civil Engineering by stating that other technical disciplines are the ones least interested in the subject.

7.5.1.2 Lack of collaboration

The concern of mistrust and lawsuit processes may cause ineffective collaboration. The typical lack of collaboration in the construction industry is caused by the predominant silo way of working, where all the benefits of a collaborative environment are lost or corrupted (Enegbuma *et al.*, 2014). BIM is about collaboration, and the fragmentation and lack of collaboration in the Dominican construction culture may difficult the spread of its implementation. Five interviewees identified the lack of collaboration as a challenge to BIM implementation in the country. In this regard, interviewee 46/I specified that there are cases where technical disciplines are not integrated since the beginning of the design concept to pay lower professional fees.

Resistance from team members to share information is another issue that affects collaboration (Eadie *et al.*, 2013a). Two interviewees pointed out that sharing information may not be widely accepted by some professionals because of the fear and lack of trust in giving out information on a project. In this regard, Interviewee G argued*:* "They are like: *"I produce this information and then it will be used later…" "They will not pay me what they should, even though there is a contract".*

7.5.1.3 Traditional way of working

Changing current and favoured ways of working and adjusting current business models to BIM is a significant challenge (Vass and Gustavsson, 2017). Four interviewees considered that the traditional way of working in the Dominican construction industry hinders the implementation of BIM in the country. Issues related to the traditional way of working include the implementation of the same methods for the last 50 years, the implementation of inefficient methods because they are widely adopted and still give them results, and the traditional methods are not compatible with BIM principles.

7.5.1.4 Lack of planning

Four interviewees stated that lack and inefficient planning in construction projects in the Dominican construction industry is prevalent. Two interviewees explicitly said that construction schedules could be prepared, but they are not always followed. Moreover, the tendency of solving problems on the go was pointed out by two interviewees, from which Interviewee G stated: *"Here we have the habit of solving problems on-site. Actually, this is a very common phrase in the industry 'I solve this on-site'".*

7.5.1.5 Lack of transparency

Interviewees stated that there is a lack of transparency in some practices of the Dominican construction industry for which some professionals may not openly welcome the implementation of BIM. Two interviewees talked about the prevailing lack of transparency in cost estimations. Furthermore, one interviewee explained how some developers tend to prepare two projects: one for the government's approval and the actual project to be constructed. Issues of this type have been identified in other countries as well. Participants of the study conducted by Li *et al.* (2017) in China opined that the improved transparency that BIM offers might decrease the contractor's possibilities of getting more profits from quantity overruns.

7.5.1.6 Insufficient provision of project's information

Insufficient provision of project's information was pointed out as a common issue within project teams. Interviewee B said that professionals tend to see projects as drawings and forget about the project's information. Interviewee D talked about how decisions tend to be taken in the last minute, on-site and with limited information of the project. Lastly, Interviewee 46/I talked about the habit of not defining projects since the beginning. In this regard, Acquah and Oteng (2018) indicated that the construction sector is an industry that highly depends on information. Therefore, regardless of BIM, these inadequate practices need to be changed in the Dominican construction industry as it affects the effectiveness of the sector.

7.5.1.7 The habit of not meeting standards

Interviewee G noted that BIM could be a tremendous change for many professionals as they are not used to follow standards, not even for simple tasks such as project' approval: *"People present their project in a particular way. Even the format of the paper size for printed drawings is not standardised. I mean, they are not applied".* This comment reflects not only a tendency from the professionals but also the negligence from governmental institutions of not systematising these processes.

7.5.2 Negative attitudes towards BIM

Xu *et al.* (2014) identified that individual's attitudes, especially inclination and interest, are an important barrier to BIM implementation. They suggest that enhancing the way of thinking of users and potential users would allow wider adoption of BIM. Several negative attitudes could be drawn from the interviewees that are not only related to BIM but also to the Dominican construction industry in general.

7.5.2.1 Resistance to change

As per Maurer (1997 in, Davis and Songer, 2008), people's resistance is the main reason for the failure of organisational change. Different aspects form individual's attitudes towards the implementation of new technology: the risks implied in the use of uncertain methods, the implicated economic uncertainties, the complexity of the new process in particular situations, and the insight of other people's attitudes towards new technology (Won *et al.*, 2013). Nine interviewees specified that professionals do not want to change their current practices. In this regard, Interviewee B argued: *"With old* *school professionals it is more like a rejection […] I feel that professionals that are older than 45 do not want",* illustrating that there is resistance to implement BIM from old professionals.

7.5.2.2 "BIM is not a priority for the country"

Three interviewees commented that they do not consider that BIM is a priority for the government at this moment. For them, there are more urgent problems in the construction sector that should be addressed before thinking ahead with new methods like BIM:

> *"[…] There are other projects in the government that have more priority than BIM. Here, there are still problems with town planning regulations, and this is more important than checking whether a project implements BIM or not. There are a lot of challenges to face before the government takes this technological step. If productive private companies have struggled with BIM, imagine the government of a developing country. We need more years for this to happen".* – Interviewee 32, Org. 26

7.6 Standardisation challenges

Ten interviewees from 6 organisations and the BIM Education interviews recognised various standardisation challenges that difficult the implementation of BIM in the country. These challenges comprehend Lack of a BIM mandate, Lack of standards and regulations in the Dominican construction industry, Deficient systematisation in governmental institutions of the Dominican construction industry and Non-existence of BIM standards in the D.R. (Refer to Figure 7.5).

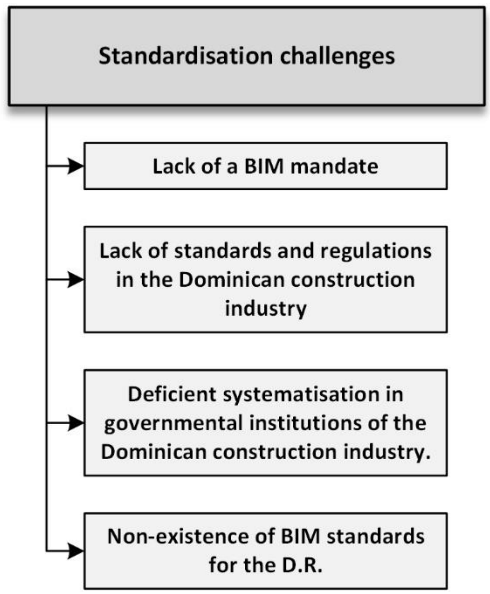


Figure 7.5 Standardisation challenges to BIM implementation in the D.R.

7.6.1 Lack of a BIM mandate

Lack of a BIM mandate was identified by four interviewees. Three interviewees considered that the implementation of BIM could not happen in the country without a mandate. On the other hand, *Interviewee 47* stated that Org. 33 would implement BIM anyway, but recognised that having a mandate from the government would help them to attain their goals.

7.6.2 Lack of standards and regulations in the Dominican construction industry

Lack of standards and regulations was also identified by four interviewees. Interviewees commented that there is a lack of regulations in the country; however, overall, this critic was very vague. On the other hand, two interviewees were more specific in the topic and stated that government institutions have deficient drawing regulations for the approval of projects: "*We never used standards to use AutoCAD. AutoCAD was adapted to the MOPC regulations: lines... You don't have a defined drawing style book in this country"* - Interviewee G. This is a very significant challenge as BIM would, then, imply a big change for a country where its 2D drafting regulations are not very well structured.

7.6.3 Deficient systematisation in governmental institutions of the Dominican construction industry.

Four interviewees talked about the lack of systematisation in these institutions, which does not comply with BIM. In their comments was emphasised that these institutions check projects rudimentarily (e.g. with the hard copy of the drawings) which forces the professionals to submit their projects this way, regardless they implement BIM or use sophisticated software to develop their projects:

> *"I need to specify to you that we adhere to the regulations in this country. And, in this context, public institutions are more behind than what we are talking about. You need to meet the requirements that they demand, which are normally based on the same methodology we have implemented in the last 20 years"* - Interviewee 50, Org. 36.

That is similar to the situation reported by Xu *et al.* (2014) in China. They concluded that it is more difficult for the government to change and adopt BIM than to the professionals of the Chinese construction industry as 2D paper drawings are still required for the evaluation of projects (in urban planning and construction bureaus).

7.6.4 Nonexistence of BIM standards

BIM standards and guidelines are generally part of a national BIM strategy (Wong *et al.*, 2010). Therefore, since the Dominican government is not involved with the implementation of BIM, no BIM standards have been established nation-wide. This challenge was identified by one interviewee: *"Well, what affects the most is the fact of not having BIM standards in this country"* – Interviewee G.

The non-existence of BIM standards in the country has forced organisations implementing BIM to follow standards from other countries, which does not entirely ensure consistency in the collaborative work between different organisations. Results in this regard were discussed in Chapter 5, Section 5.4.3.3.

7.7 Initiatives to propel the implementation of BIM in the Dominican construction industry

Interviewees from the main study were also enquired about which actions they consider necessary to drive the implementation of BIM in the country. Interviewees suggested several initiatives of different nature, which were grouped into the following categories: Provision of BIM Education, Government leadership and BIM diffusion in the industry (Refer to Figure 7.6).

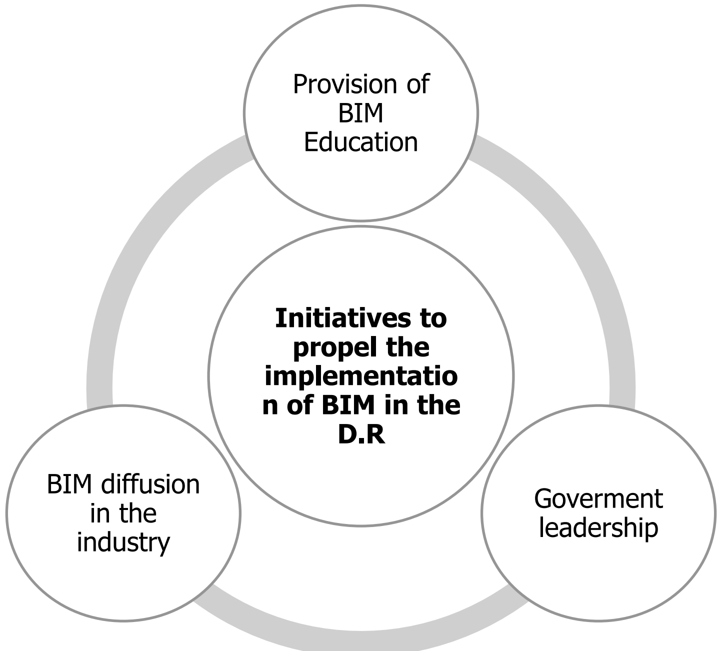


Figure 7.6 Initiatives to propel the implementation of BIM in the Dominican construction industry

7.7.1 Provision of BIM Education

Thirty-six interviewees, all the interviewees related to BIM Education and from 23 construction organisations, stated that education is highly needed to spread the implementation of BIM in the country. The initiatives suggested in this regards are presented below.

7.7.1.1 BIM education through higher education institutions

The main educational initiative proposed by 28 interviewees, from the BIM Education interviews and the 17 organisations, was the provision of BIM education in higher education institutions. Thirteen interviewees provided several reasons as to why the delivery of BIM Education is the responsibility of academia: *'universities should teach*

BIM to prepare the new professionals', *'universities are the best means to prepare current professionals in BIM implementation'*, *'education offered in universities is better than any other mode of course'*, *'offering BIM in universities will benefit construction firms because they will acquire BIM skilled personnel'*, *and 'raise BIM awareness among current students'*. Despite all these positive aspects, Interviewee F expressed his concern on why the initiative of integrating BIM in the curricula may not be completely effective:

> *"For you to see how ironic this situation is, one day I think they should, another day think they shouldn't. Why? Because the BIM curriculum is a curriculum that is more convincing as you get experience. I mean, if we teach BIM to a student in Design I, he will retain a 1% of what you taught him. If you teach a student in Design X, he will retain 80%. If the person has built, has graduated from university and you taught him many things, he will retain 100%."*

7.7.1.2 BIM training

Furthermore, nine interviewees considered that, besides BIM education, BIM training in higher education is also necessary for the implementation of BIM in the country. Three interviewees explicitly stated that BIM training could be an option for current professionals that did not have the opportunity to study BIM in their undergraduate degrees.

Other educational strategies proposed by the interviewees include *BIM education events* (4 interviewees), *Educate governmental institutions* (2 interviewees), *Educate private clients* (1 interviewee), *Educate academics in BIM* (1 interviewee), *Elaborate a BIM education plan* (1 interviewee), and *Mandatory education to update professionals established by professional bodies* (1 interviewee).

7.7.2 Government leadership

The involvement of the government was suggested by 22 professionals from 14 construction organisations and the interviews related to BIM. Seven interviewees expressed their opinion as to why the implementation of BIM in the country should be the responsibility of the government. Comments such as *'The government is more powerful and effective than the private sector'*, *'The government can mandate a unique implementation of BIM that will be followed by everyone'*, *'International examples of successful implementation are from government mandates'*, *'It is the most effective option to raise awareness among the professionals of the Dominican construction industry'*, and '*We need a BIM awareness campaign that can only be afforded by the government'* illustrate their outlook. Interviewees outlined different strategies that the government could implement to propel the implementation of BIM, from which BIM mandate was identified as vital.

7.7.2.1 BIM mandate

Sixteen interviewees noted that mandating BIM could impulse its implementation significantly. Interviewees gave the general suggestion of *'BIM should be mandated* *nationally',* and *'BIM should be mandatory'*. In contrast, others were more specific by suggesting that BIM should be mandated in construction biddings (2 interviewees) and in governmental institutions that approve construction projects (13 interviewees). Furthermore, eight interviewees stated the reason why this latter strategy would be a good initiative from the government: *'To improve the current processes of projects' approval in the country'*; *'To encourage the implementation of BIM in the private sector'*; *'It is the only effective way to drive the implementation of BIM'*; *'The implementation of BIM would not be effective without the involvement of these institutions'*; and *'It has been done in other countries'.* In terms of how this should be attained, Interviewee D opined that this should be demanded gradually, while Interviewee 48 said that it should be required only in projects of a specific size.

It was interesting to discover that some of these institutions already have initiatives related to the use of BIM. According to Interviewee D, the Ministry of Public Works and Communications (MOPC) is aware of the advantage of using parametric software as they ask professionals to submit a model in the software ETABS to check and approve the Structural design of projects. Furthermore, Interviewee G stated that there is interest in BIM from the City Council and Minister of Public Works of the Northern city San Francisco as some employees were enrolled in the BIM Diploma course he delivers.

The remainder suggestions for a government leadership included *Create regulations* (7 interviewees), *Develop an agenda/strategic plan* (3 interviewees), *Use of BIM in* *governmental institutions* (2 interviewees), *Regulate professionals' salaries* (1 interviewee), and *Create of a BIM institution* (1 interviewee).

7.7.3 BIM diffusion

Nineteen interviews from 12 construction organisations and the interviews related to BIM education posited the diffusion of BIM in the industry. Players suggested for this initiative include BIM adopters, BIM-centred organisations, and professional bodies and associations.

7.7.3.1 BIM adopters

Seventeen interviewees related to BIM education and from 9 organisations considered that the construction organisations and professionals, need to take the lead to propel the implementation of BIM in the country, mainly due to the current lack of interest in BIM from the government:

> *"The professionals need to take action because the government won't do anything"* – Interviewee 21, Org. 12

Nine interviewees argued that this could be attained by engaging in the implementation of BIM to set an example within the industry. Seven interviewees suggested that these early adopters should promote their work. Lastly, three interviewees proposed that these players should introduce BIM to the public sector to expand the diffusion.

7.7.3.2 BIM-centred organisations

Four interviewees related to BIM education and from 4 organisations opined that it is necessary to create communities of professionals to support the implementation of BIM in the country: *"Groups of professionals need to be created for this purpose. We need to join."* – Interviewee 20, Org. 12*.*

This study defined this type of organisations as "BIM-centred organisations". These are organisations created exclusively to drive, promote and give support to the industry for BIM. Their primary role is the creation of networks as they can involve the participation of different stakeholders from the government, the industry and Academia.

7.7.3.3 Professional bodies/Industry Associations

Four interviewees related to BIM education and from 3 organisations considered that existing Dominican professional bodies should promote BIM among professionals. In this regard, the Director of the Continuing Education Department of the Headquarters of Professional Body A commented:

> *"[…] I consider Professional Body A is a key point for the diffusion of BIM because BIM can be even taught in a university, but all these professors need to be members of the Chartered Institute […] If we diffuse BIM from this institution, people will know about it because people follow Professional Body A [...] We have diffusion channels with forums in all the institutions"* - Interviewee E*.*

Figure 7.7 summarises all the initiatives to propel the implementation of BIM in the Dominican construction industry suggested by the interviewees.

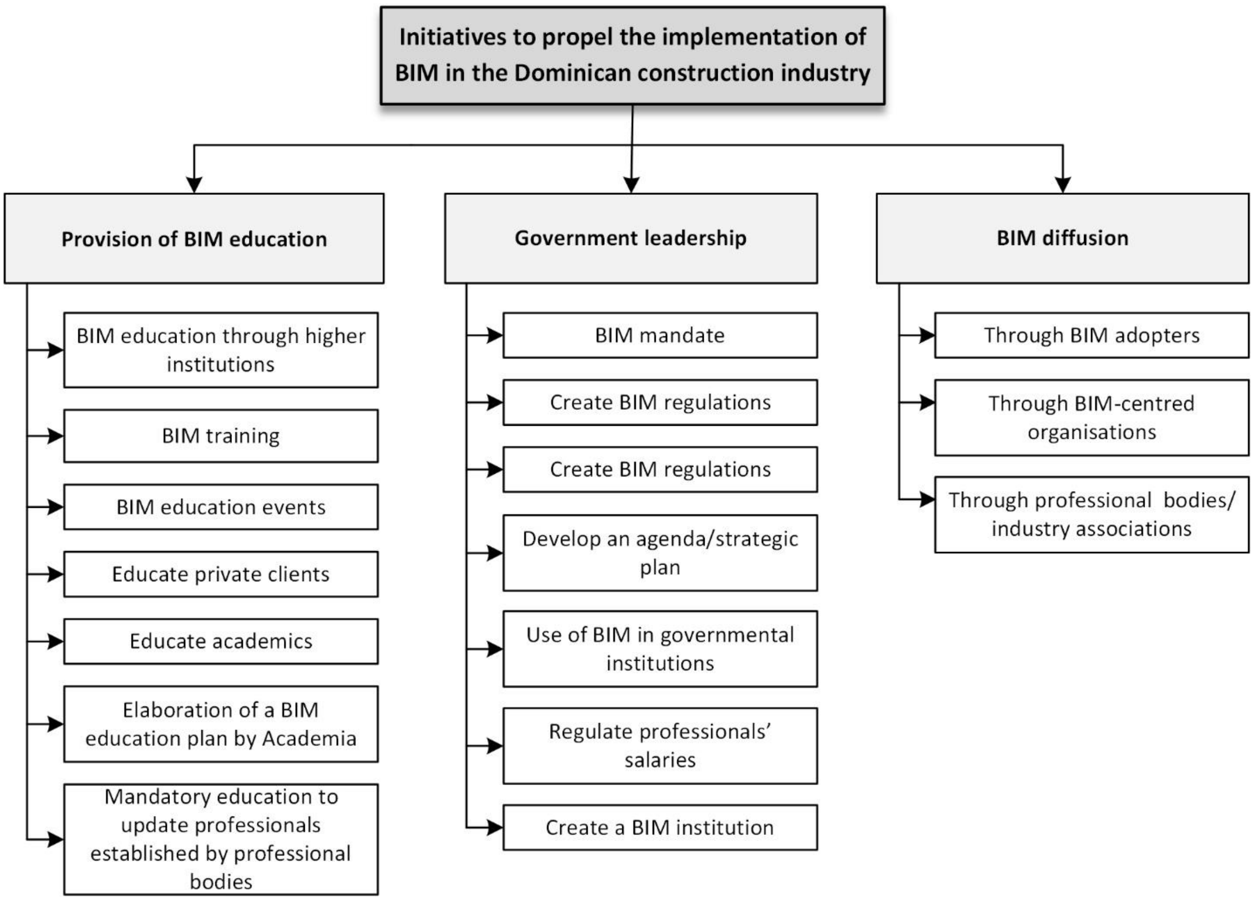


Figure 7.7 Detailed initiatives to propel the implementation fo BIM in the Dominican construction industry

7.8 Summary

This chapter presented the challenges to BIM implementation in the Dominican Republic identified by the participants of the main study. These challenges are Inter-organisational/Environmental, Educational, Economic, Cultural and Standardisation challenges (Refer to Table 7.1).

Table 7.1 Summary of challenges identified by the interviewees

Challenges category	Detailed challenges
Inter-organisational/Environmental challenges	- Lack of government support - Lack of client demand
Educational challenges	- Lack of BIM education: Lack of BIM knowledge among professionals, Lack of BIM knowledge among academics, Lack of BIM experienced professionals, and BIM education focused on software skills. - Deficiencies of current Education delivered in careers related to the industry.
Economic challenges	- Related to BIM: High investment in software, hardware and training - Related to the organisation: Lack of financial capacity of most construction organisations in the country and the prevalent unwillingness to invest in innovation in Dominican construction organisations
Cultural challenges	- Characteristics and way of working of the Dominican construction industry: Technological backwardness of the Engineering field, lack of collaboration, the traditional way of working, lack of planning, lack of transparency, insufficient provision of project's information, and habit of not meeting standards - Negative attitudes towards BIM: Resistance to change and "BIM is not a priority in the country".
Standardisation challenges	- Lack of a BIM mandate; - Lack of standards and regulations in the Dominican construction industry; - Deficient systematisation in governmental institutions of the construction industry; and - The non-existence of BIM standards in the country.

Besides identifying the different challenges that affect the Dominican construction industry, the interviewees proposed various initiatives to propel the implementation of BIM which were grouped in the following categories: Provision of BIM education, Government leadership, and BIM diffusion in the industry.

The next chapter (i.e. Chapter 8) will discuss the overall findings of this study, the development of the framework and its validation process.

CHAPTER 8: A FRAMEWORK FOR IMPLEMENTING BIM IN THE D.R.

8.1 Introduction

This chapter discusses the development and validation of the framework for implementing BIM in the Dominican Republic, which corresponds to the sixth objective of this research.

A framework is defined as “a system of rules, ideas, or beliefs that are used to plan or decide something” (Cambridge University Press, 2017). Kassem *et al.* (2014) indicated that the increasing implication of BIM in the construction industry suggests the need for frameworks and protocols to transmit knowledge, promote adoption and increase uniformity in the implementation.

Due to the novelty of BIM, many researchers and industry players have identified the need and have created BIM-related frameworks and models for different purposes. Jung and Joo (2011) proposed a framework to explain the various dimensions where practical BIM implementation takes place. Succar (2009) developed a framework to provide a BIM knowledge structure that allows a better understanding of BIM. The EU BIM Task Group (2017) developed a Framework for Public Sector BIM Programmes to provide a common approach for BIM implementation in the European Public sector. Other frameworks have been developed to guide the implementation of BIM within organisations (Mihindu and Arayici, 2008; Autodesk, 2010; Gu and London, 2010; Autodesk, 2012; Panaitescu, 2014; Chen, 20150) and small organisations (Coates, 2013; Al Awad, 2015); to measure the BIM readiness in organisations (Haron, 2013), and BIM adoption indices (Enegbuma *et al.*, 2014); to investigate factors influencing BIM adoption in an industry context (Xu, Feng and Li, 2014; Ahuja *et al.*, 2016), assess BIM acceptance in individuals and organisations (Lee, Yu and Jeong, 2015); and BIM training frameworks for companies (Kumar, 2015). Also, there are frameworks to assist in the integration of BIM in higher education curricula (Refer to Section 8.4.1.5).

From this summary, it can be noted the full range of themes BIM-related frameworks can cover. That opened the discussion of the need for a framework and what needs to be considered to develop a framework that facilitates the implementation of BIM in the Dominican Republic. Discussions on both aspects are presented in this chapter.

The framework was developed through an extensive literature review on BIM frameworks and the data obtained and analysed from the interviews.

This chapter is divided into four parts. The first part presents findings from the data collected to provide an overview of the status of BIM in the Dominican Republic. The second part discusses the need and content of the framework according to the findings from the data collected and interviewees' suggestions. The third part discusses the structure and type of framework that was developed. Then, the framework and its components are explained in detail. Lastly, the fourth part presents the validation the framework.

8.2 Status of BIM in the Dominican Republic

As shown in Figure 8.1, currently, there is only Academia and Industry leadership in the Dominican Republic in terms of BIM, which is a bottom-up approach as indicated by Succar and Kassem (2015). In a bottom-up approach, small organisations diffuse BIM within a market by influencing other small organisations (horizontal diffusion) and large organisations and industry organisations (upwards diffusion) to adopt BIM. That approach depicts the starting point of BIM in the Dominican Republic, not only in BIM implementation but also in BIM education/training, as stated in Chapter 5 and 6.

Academia is assuming the educator role primarily through training. Initial stages of integrating BIM in the Civil Engineering curriculum of an important university in Santo Domingo have been identified, which is a significant advancement for the country in terms of BIM education. Furthermore, several universities are promoting BIM to students and professionals through events such as seminars and conferences. Both BIM training and the different events hosted by universities have been realised by collaborating with stakeholders from the industry (dual collaboration) (Refer to Figure 8.2).

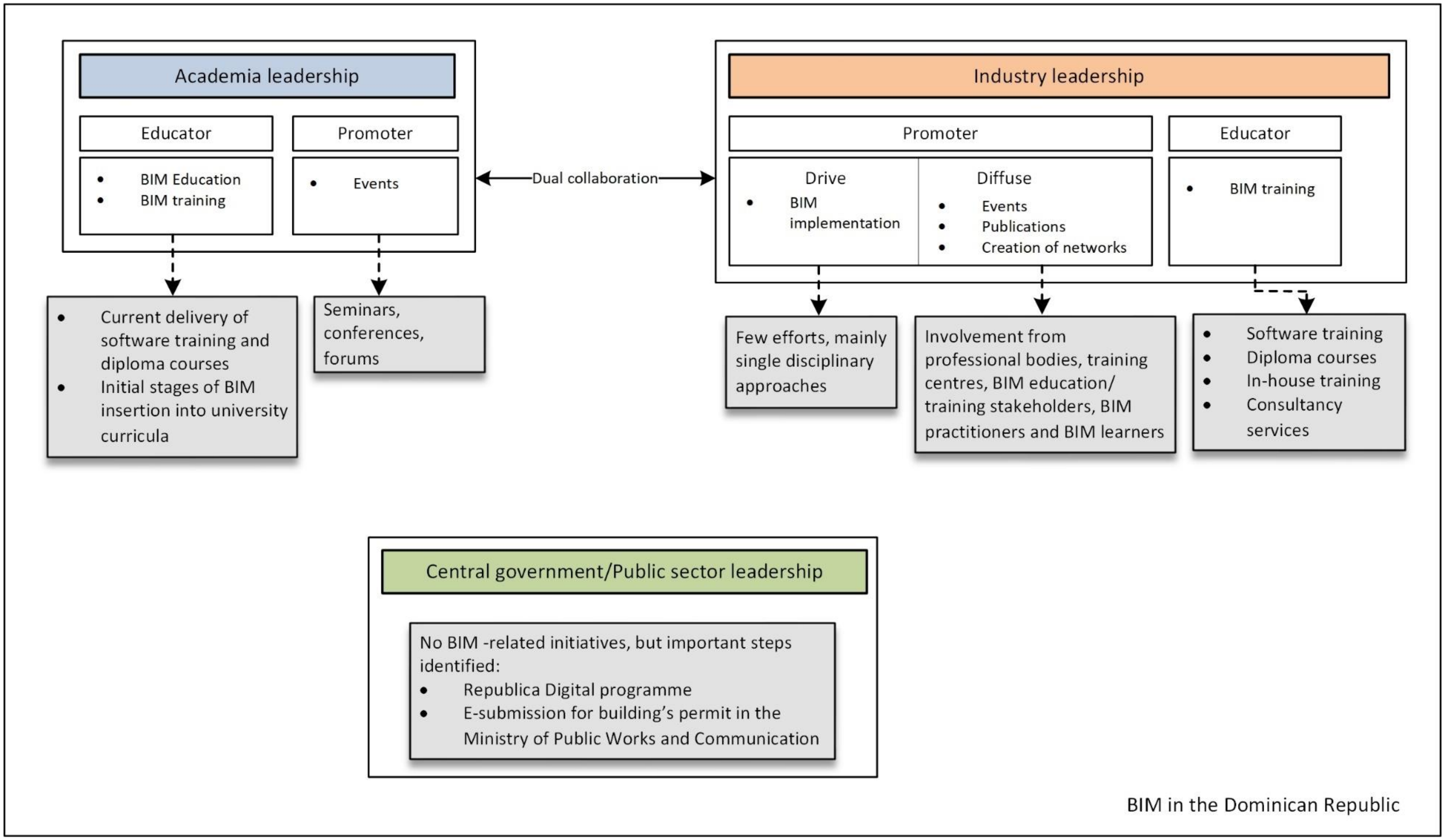


Figure 8.1 Status of BIM in the Dominican Republic

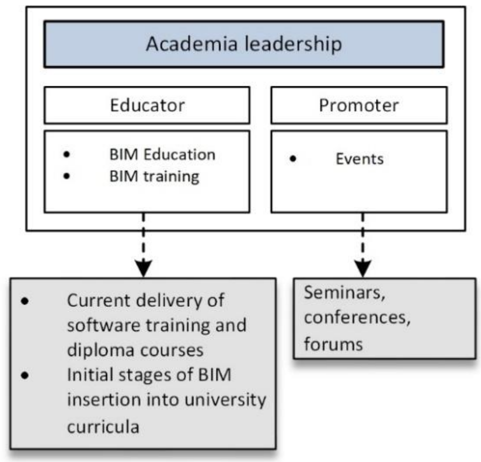


Figure 8.2 Academia leadership on BIM in the D.R.

As presented in Figure 8.3, the BIM leadership in the Dominican construction industry is primarily realised through BIM implementation in construction organisations and the diffusion of BIM knowledge. Nonetheless, the number of organisations implementing BIM is limited. The few efforts identified have not been adequately realised and are mainly single disciplinary due to the relevance and wide range of intra-organisational and inter-organisational barriers affecting these organisations (Refer to Chapter 5, Section 5.4.2.3 and 5.4.3.2).

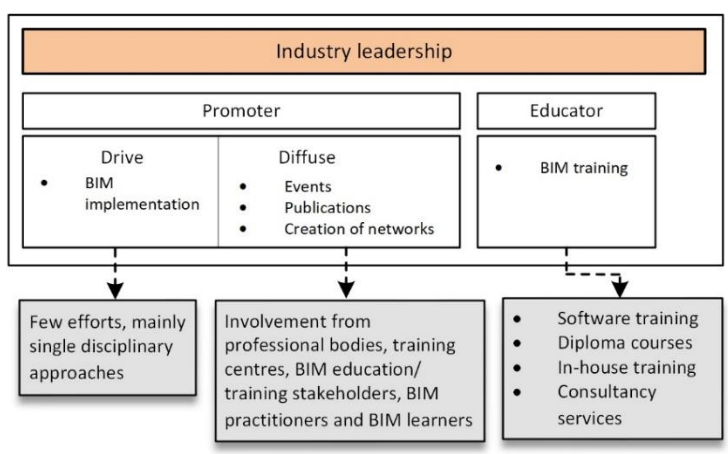


Figure 8.3 BIM leadership of the Construction industry in the D.R.

Concerning the diffusion of BIM knowledge, this has been a critical activity in the last years. Many events have been arranged through the collaboration of different players within the industry (professional bodies, training centres, BIM training stakeholders, BIM practitioners and BIM learners). As previously stated, a dual collaboration between Academia and industry players has been crucial in preparing these events.

In terms of education, there is the availability of BIM training in the form of software training and diploma courses delivered by training centres and BIM training stakeholders. Moreover, BIM training stakeholders offer customised services to construction organisations through in-house training and consultancy services for organisations to develop strategies to implement BIM in their practices.

Regarding the strongest leadership, the central government and public sector leadership, the Dominican government has not expressed any interest in implementing BIM yet. Nonetheless, important initiatives have been identified which represent future opportunities for BIM (Refer to Chapter 3, Section 3.5):

- Republica Digital, from which has been created the project “City Councils connected”, that thus far has allowed 80 city councils to offer services over the internet. This project constitutes an advancement for the Dominican construction industry because it is setting the path for city councils to be able to provide in the future digital permission services to construction projects, such as planning permissions.

- The e-submission for building's permit in the Ministry of Public Works and Communications (MOPC) is another crucial advancement as this can be seen as a starting point for the introduction of innovative and efficient building's permit procedures in public institutions (Refer to Figure 8.4).

Figure 8.4 Current status of the central government and public sector in terms of innovation

Findings corroborate that BIM is in an infancy stage in the D.R and the country can be denominated as BIM infant country. Rogers *et al.* (2015) proposed the term BIM infant country to define a country whose construction industry does not develop any project with BIM; however, it is interested in implementing BIM in future. The interest in BIM in the D.R. has been confirmed in this study through the industry professionals and people related to the spread of BIM knowledge, training and education.

8.3 The need for a framework and framework's content

The need for a framework was evaluated from the outlook of the participants and the data analysed from the interviews. Interviewees from the main study were asked if they considered that a framework (previously considered as a toolkit) would be beneficial to propel the implementation of BIM in the country (Refer to Figure 8.5). Thirty-two interviewees from the interviews related to BIM Education and from 20 organisations, opined that it would aid the implementation of BIM in the country, which accounts for a 76%. Since this framework was an undefined product, some interviewees (Interviewees C, D, 18 from Org. 13 and 49 from Org. 35) stated that they were not able to answer this question. Moreover, 5 interviewees from 4 organisations expressed that a framework was not necessary. Instead, they pointed out other strategies that may work better such as the creation of tutorials from software providers (Interviewee 26 from Org. 26), provision of BIM education (Interviewee 23 from Org. 12, 36 from Org. 25, and 23 from Org. 12), and a BIM campaign developed by different institutions of the industry (Interviewee 30 from Org. 19).

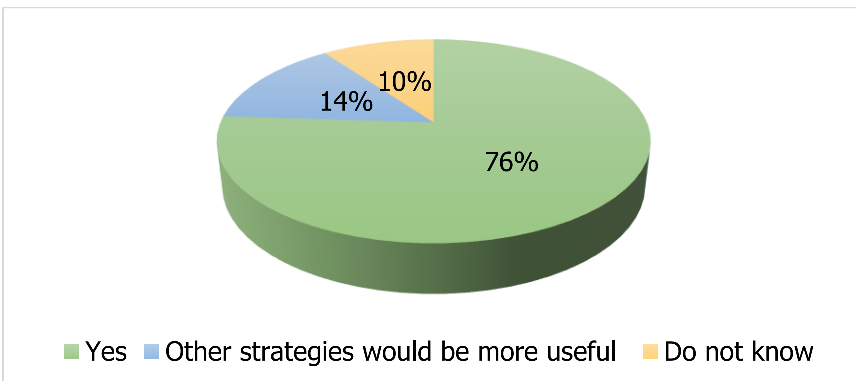


Figure 8.5 Need for a framework as per interviewees' opinion

Furthermore, as presented in Chapter 7 (Section 7.7), interviewees from the main study suggested diverse initiatives to propel the implementation of BIM in the country which were categorised into the following: Provision of BIM education, Government leadership and BIM diffusion. Findings from the study of BIM education in the country also suggested the need for guidance for integrating BIM in university curricula, for which a framework was proposed (Refer to Chapter 6, Section 6.7). All these results were considered, and it was determined that the framework must have a component to guide educational institutions to integrate BIM in university curricula and another component to guide governmental and public institutions in the development of a BIM mandate. The BIM diffusion was not included in the framework as it suggested the involvement of many players (BIM adopters, BIM-centred organisations, and professional bodies and associations) and a myriad of activities of different nature (events, training, consultancy service, etc.).

As previously explained, interviewees were enquired if it would be beneficial to develop a framework (previously considered as a toolkit) for the aim of this study. The fact that this question was referring to a product under development arose the curiosity of various interviewees who made suggestions about how the framework should be. As presented in Figure 8.6, the main suggestion from the interviewees was to develop a framework directed to construction organisations.

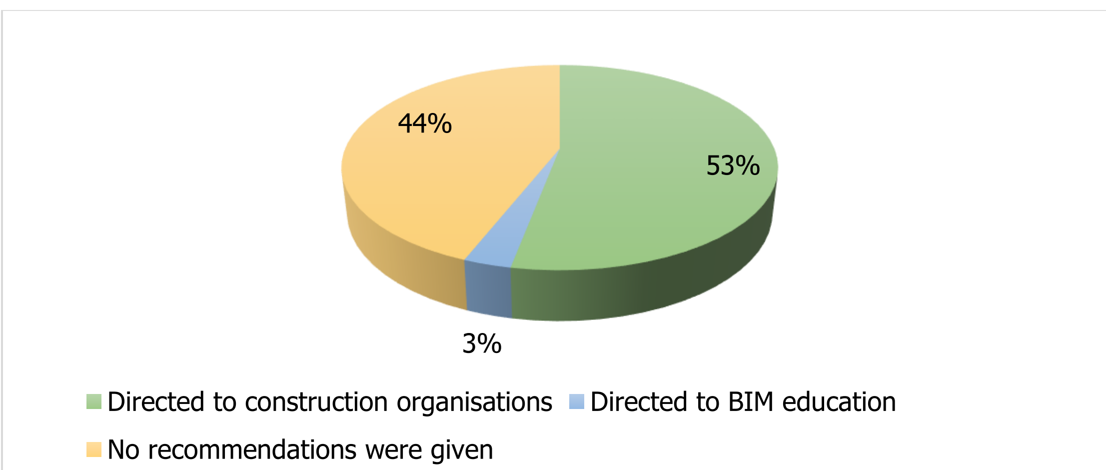


Figure 8.6 Interviewees' suggestions on framework content

Seventeen interviewees, from the interviews related to BIM education and from 9 construction organisations, considered that the framework should be directed to construction organisations. The reasons why some thought of this idea can be illustrated with the following comments: *'to motivate the implementation in the industry'*; *'(it) would help construction organisations that are afraid of implementing BIM'*; *'(it) would provide knowledge, clarify things and help companies to understand the benefits of BIM'*; *'(it) would accelerate the process of implementing BIM in construction companies'*; *'(it) would be used by construction companies because BIM is of global interest'*; and *'Dominican construction organisations need a guide for BIM'*.

These opinions, the issues encountered in the organisations in transition to implementing BIM and implementing BIM, and the openness to implementing BIM of most of the organisations that do not currently implement BIM suggested the need to guide construction organisations in the implementation of BIM. Thus, the framework has a third component to guide construction organisations in the implementation of BIM.

8.4 Development of a framework to facilitate the implementation of BIM in the Dominican Republic

Due to the infancy of BIM in the country, many aspects were suggested and considered for the framework. As a result, a comprehensive framework was developed containing three frameworks directed to the key players that can drive the implementation of BIM in the Dominican Republic. These key players belong to each of the necessary leadership to implement BIM in a country (Refer to Chapter 3, Section 3.4). The framework provides a guide that each player can follow to perform critical roles and drive the implementation of BIM successfully:

- **Academia:** Framework to guide the integration of BIM into university curricula
- **Construction organisations:** Framework to guide the BIM implementation process in construction organisations.
- **Central government and public sector:** Framework to guide the development of a BIM mandate.

Before developing the framework, it was important to identify the type of framework that was going to be developed. The classification of frameworks from the field of Knowledge Management (KM) has been adopted to study existing BIM frameworks (Kassem *et al.*, 2014) and were used in this study to identify the nature of the framework to be developed. Knowledge management frameworks are classified into three categories: descriptive, prescriptive and hybrid (Rubenstein-Montano *et al.,* 2001). Descriptive frameworks aim to characterise a current complex phenomenon by describing and simplifying its knowledge domains. On the other hand, prescriptive frameworks prescribe methodologies to follow (Holsapple and Joshi, 1999; Kassem *et al.*, 2014). Lastly, hybrid frameworks are a combination of both descriptive and prescriptive frameworks (Mentzas, 2001; Rubenstein-Montano *et al.*, 2001). This study adopted a hybrid approach because it was considered necessary to include both knowledge and methodologies to follow to fulfil the aim of the framework. The hybrid approach of the framework is mostly prescriptive, providing a set of steps that the players above can follow to perform their key roles. The descriptive elements of the framework provide the information that the players need to assume their roles and accomplish each step effectively.

8.4.1 Framework to guide the integration of BIM into university curricula

The framework dedicated to Academia which intends to guide the development of a BIM education plan to integrate BIM into university curricula was created from a literature review on BIM Education and the analysis of existing BIM education frameworks worldwide. The first version of the framework was conceived under the name *"BIM education framework for clients and professionals of the construction industry"* where guidance is given not only to Academia but also to the industry to elaborate a BIM education plan (Refer to Appendix 8-A). Two academic publications resulted from this framework: A conference paper (Silverio *et al.*, 2016) and a journal article (Silverio *et al.*, 2017).

For this framework, a thorough literature review on the subject was carried out, which is succinctly presented in the following sections.

8.4.1.1 BIM Education in Academia

BIM education is the solution to accelerate the BIM learning curve; thus, firms can employ ready-made BIM professionals (Wu and Issa, 2013). There are several stakeholders involved in the delivery of BIM education: Academia, construction firms, software companies, BIM training centres, professional associations and BIM learners

(AIA-CA, 2012; CIC, 2013; Rooney, 2017). Academia is the primary provider of BIM education; while the rest provide BIM training, which is an integral part of the process of BIM education (Silverio *et al.*, 2017a).

It is widely believed that the fundamental education needed to overcome the lack of skilled professionals is required from higher education institutions (Miller *et al.*, 2013). Currently, higher academic institutions worldwide are either researching or have started to integrate BIM into multidisciplinary curricula at undergraduate and post-graduate levels (Sabongi, 2009; Wong *et al.*, 2011a). Nonetheless, they have been criticised for their inadequate approaches, and the quality of many academic programmes have not met the industry's and student's expectations (Wu and Issa, 2013). For successful integration of BIM in academia, there have been suggested two main actions: the creation of frameworks to guide and assist the process and the alliance of Academia and the industry (Macdonald and Mills, 2011; AIA-CA, 2012; Macdonald, 2012; Macdonald and Granroth, 2013; Byrne, 2015).

8.4.1.2 Challenges of integrating BIM in Academia

Research has documented numerous challenges that hinder the integration of BIM in Academia. Table 8.1 presents a summary of these challenges, categorised in the following categories: Curricula development, Cultural issues, Issues related to the and essence and time of BIM in the industry, and High cost.

Table 8.1 Challenges for inserting BIM in Academia

Source: Silverio *et al.* (2016; 2017a)

Topic	Challenges identified
Curricula development	- Lack of space in the curriculum to introduce new courses to the existing curriculum; - Objection to modify the curriculum to include BIM when there is the possibility that another technology process could substitute BIM in a few years (Sabongi, 2009); - Doubts if BIM should either be included in current curricula of AEC disciplines or be provided as a particular subject on its own (Miller *et al.*, 2013); - Inquiries on how to adapt new subjects into an already full curriculum (Macdonald, 2012); - How the insertion of BIM can affect the accreditation status of the curriculum (Kocaturk and Kiviniemi, 2013; Suwal *et al.*, 2013); - The restricted number of programs (required or optional) that students can take in the term they are waiting to complete their courses (Sabongi, 2009); - Programs focus mostly on software skills (N. Lee and Hollar, 2013; Rooney, 2017); - BIM treated as a design tool only (Wong *et al.*, 2011a); - The insertion of BIM in simple, intensive and isolated courses (N. Lee and Hollar, 2013; Magiera, 2013).
Cultural issues	- Several academics still see BIM as a CAD software that students should learn by themselves in their own time (Becerik-Gerber *et al.* 2011); - Resistance to change traditional teaching methods which have been implemented over many years; - Reluctance from people that have built their expertise to adopt a new concept where they are not experienced or be trained again in a field they are not accustomed to; - Students are educated as traditionally: separated per departments and with minimum or no union or collaboration among other disciplines; - There is an incapacity to connect the traditional silos that are present in the architecture, engineering and construction schools (Macdonald, 2012). - Lack of support from faculty administrators and colleagues; - Lack of interest or reluctance from students to scrutinise the new technology (Sabongi, 2009); - Doubts if the creative artistic expression can be possible within a collaborative practice; - Uncertainties if professionals can preserve and defend their values in this innovative, cooperative and democratic pluralism (Kocaturk and Kiviniemi 2013)
Issues related to the and essence and	- Technologies typical of a BIM process tend to evolve very quickly, and academics that have been kept out of the industry for some time may feel overwhelmed when attempting to keep updated (Macdonald, 2012); - Lack of knowledge and experience of academics (Becerik-Gerber *et al.*, 2011;

time of BIM in the industry	Gardner *et al.*, 2014; Kugbeadjor, Suresh and Renukappa, 2015; Rooney, 2017); - How the current personnel will adapt to the new skills and understanding demanded by BIM (Kocaturk and Kiviniemi 2013); - BIM needs a determined knowledge of business practice and workflow which is hard to simulate in a teaching course (Magiera, 2013); - Shortage of books and other training materials (Magiera 2013, Gardner *et al.*, 2014, Sabongi, 2009); - Incertitude of which BIM platform (e.g., Revit, Bentley, etc.) will become predominant (Sabongi, 2009); - The time that the implementation of BIM implies (Becerik-Gerber *et al.* 2011).
High cost	- BIM demands the use of state of the art IT equipment and high-priced software, and it can be difficult for universities to get the correct IT environment (Hogle, 2013; Magiera, 2013); - Similar to what happens in the industry, there is mistrust among the professionals in Academia and questions such as "who is responsible for" and "who will pay for" multidisciplinary courses can arise (Macdonald, 2012).

8.4.1.3 Enhancing BIM for tertiary and higher education

In the presence of these challenges, several researchers have suggested key strategies to overcome these challenges and improve the way BIM education is currently delivered in higher education. These include:

- Full programs should be reviewed and reformulated, focusing on the changes that BIM implies.
- Almost all the disciplines need to change their current curricula to include BIM as one of the main subjects.
- International academic accreditation or national level accreditation should be introduced to incentivise academic institutions.
- There should be a common framework to specify the requirements of what and how BIM topics could or should be integrated into the curricula (Suwal *et al.*, 2013).

- Include collaboration requirements and BIM technical abilities within the new/modified BIM curricula to enhance the abilities of graduates (Gardner *et al.*, 2014).
- Incorporate practical implementation of subjects and problems reported in real situations (Kumar, 2015).
- The collaboration of the students in the process of creating a programme and developing a curriculum (Wong *et al.*, 2011a).

8.4.1.4 Collaboration between Academia and industry players

Collaboration between Academia and industry players is highly suggested to increase the benefits of BIM implementation (Lee and Hollar, 2013), overcome the lack of BIM skilled professionals in the industry (AIA-CA, 2012; Hogle, 2013), and update academics (Macdonald and Mills, 2011). Several authors have identified the benefits of this type of collaboration:

- Educators teaching BIM-related programmes in Academia should keep in contact with industry players to integrate and redesign the content of the programmes following industry tendencies and practices (Lee and Hollar, 2013). That will also help to bridge the gaps between theory and knowledge from the experience of industry BIM experts (Wu and Issa, 2013).
- Opportunities for students to research on new technologies and processes, a challenging task for the industry itself due to lack of time and resources (Hogle, 2013).

- A better definition of the specifications of BIM-related careers/courses/modules and the expectations of BIM education learning outcomes.
- Provide tangible incentives to draw attention and encourage students in BIM oriented career paths. For instance: formal BIM programmes such as internships and coops, interdisciplinary BIM education, intercollegiate BIM education collaboration, and lab facilities.
- Create activities to propel BIM education. For instance, direct pedagogic contributions by industry BIM experts, knowledge sharing between academics and professionals through conferences or workshops (Wu and Issa, 2013), site visits, case studies, and industry visiting lecturer opportunities (Hogle, 2013).
- The industry can indicate the significance of material, allowing students to become betters hires (Hogle, 2013).
- Integrate practical learning methods in BIM curricula through modules sponsored by the industry.
- Create knowledge transfer partnerships connecting academics and industry players to produce training programs that provide exactly what the industry demands (Byrne, 2015).
- Create BIM teaching material with the participation of Academia, industry experts and software developers. An online collaboration platform would be of great help for this type of initiative (Suwal *et al.*, 2013).
- Creation of frameworks to integrate BIM in existing curricula and create new BIM curricula (Byrne, 2015).

8.4.1.5 Study of existing frameworks to assist the integration of BIM in academia

The need for frameworks to support the implementation of collaborative design and BIM education in higher education institutions has been posited before (Macdonald, 2012; Macdonald and Granroth, 2013; Macdonald and Mills, 2011). Table 8.2 presents a non-exhaustive list and summary of frameworks that have been created for this purpose. From all these frameworks, the Learning Outcomes framework is based on the Level 2 BIM mandate in the UK. The remainder frameworks are the result of initiatives from Academia and industry players.

The development of the framework to guide the integration of BIM in Academia in the D.R. has been informed by the IMAC, the New Zealand's National Draft and the Collaborative BIM education framework from the BIM Education Working Group (EWG). That is because these frameworks were not created based on a BIM mandate, which is the current context of the Dominican Republic in terms of BIM.

Table 8.2 Existing frameworks to assist the insertion of BIM in academia

Source: Silverio *et al.* (2016; 2017a)

Framework	Sections	Points covered	Actors involved
IMAC framework (Australia) Code BIM Project: Australian Office of Learning and Teaching (OLT) along with the University of Technology Sydney, University of South Australia and University of	Stages of the framework: Illustration Manipulation Application Collaboration	Provides a benchmarking tool and a guide to assist academics in the insertion of collaborative design education and BIM in AEC curricula.	Providers: Academia Beneficiated: Students (levels not specified)

Newcastle *(MacDonald, 2012; (Macdonald and Mills, 2011; Macdonald and Granroth, 2013)*			
New Zealand's national draft framework: The University of Auckland *(Miller et al., 2013).*	Includes the three types of education that the study considers necessary in a BIM educational framework: - Vocational training and continuing professional development; - Degree Programmes (Undergraduate and Masters); - Research (including PhDs). The requirements of each type of education are explained in three domains encompassed in the implementation of BIM: Architecture, Engineering, and Construction; Software and Technologies; Business, Enterprise, and Management.	Specifications of learning outcomes demanded by Vocational Training/Continuing Professional Development (CPD) in the three domains; Proposes the insertion of BIM in existing bachelor's degree's curricula Proposes the creation of Integrated BIM masters; Considers to carry out research in further areas than the ones presented in the framework.	Providers: Academia CPD providers Beneficiated: Current practitioners Undergraduate, masters, and research students
Collaborative BIM education framework from the BIM Education Working Group (EWG) (Australia) *(AIA-CA, 2012; Succar and Sher, 2014)*	Components: A: Identifying BIM Competencies B: Classifying BIM Competencies C: Arranging competencies and designing BIM learning modules D: An industry framework for professional development E: An academic framework for BIM Education F: The BIM Institute	Identification of BIM competencies; Creation of an online BIM learning hub; Creation of BIM learning modules; Creation of BIM learning materials; Creation of an Industry framework for professional development in the industry; Expansion of existing and creation of innovative CPD programmes Creation of an Academic framework; Expansion of existing and creation accredited programmes. Creation of a BIM institute.	Providers: Academia Industry Other BIM education providers Beneficiated: Students (levels not specified) Current practitioners

Learning Outcomes framework (UK) **BIM TASK GROUP and BAF** (BIM Task Group, 2012; Underwood *et al.*, 2013; Underwood *et al.*, 2015; BIM Level 2, 2016)	Categories of the initial framework: Strategic; Management; Technical. Categories of the final version: Understand the essence BIM, BIM Level 2 requirements established and its relationship with the Government Construction strategy 2025; Understand the implications and value of BIM in the organisation; Understand the requirements for information management and exchange described in the 1192 suite of standards PAS55 / ISO 55000.	Provides the learning outcomes (LOF) needed to implement BIM level 2 successfully. It can be applied in both the industry and Academia. For the implementation in Academia, the LOFs are specified for undergraduate levels (4, 5 and 6) and post-graduate level (7).	Providers: Academia Industry Beneficiated: Current practitioners Undergraduate and post-graduate students

8.4.1.6 Updated framework

Several changes were made to the initial framework developed in this study (Refer to Appendix 8-A) to incorporate it into the comprehensive framework. Firstly, the framework was split into two. The part dedicated to Academia comprehends now one framework. In contrast, the part related to the industry was refined and incorporated into the framework dedicated to the construction organisations, which is explained in Section 8.4.2.

The first version contained three stages: Strategy, Implementation and Revision stage. The updated framework dedicated to Academia comprehends now four stages: Strategy, Preparation, Realisation and Revision. Lastly, the framework was graphically improved to facilitate its understanding (Refer to Figure 8.7).

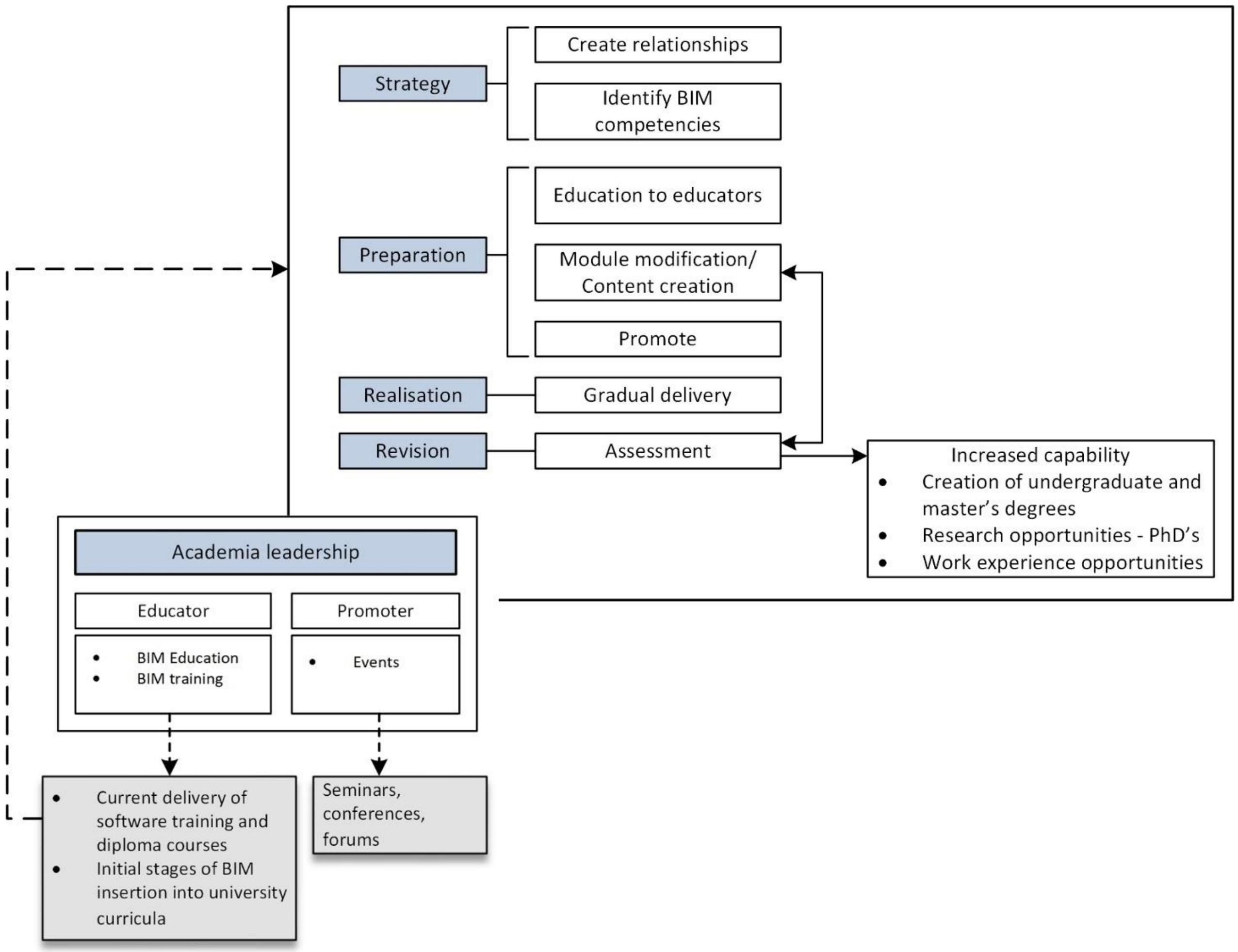


Figure 8.7 Framework to guide the integration of BIM in Academia

8.4.1.6.1 Stage 1: Strategy

The first stage in this process is the development of the strategies to be followed. For that, it is necessary to establish a lead. The best option for this purpose is to create formal relationships between academics and people from the industry interested in the integration and improvement of current approaches to BIM Education. In the D.R., players of the industry that can be part of this process comprehend professional bodies, BIM training centres, BIM training stakeholders, BIM adopters (professionals and construction organisations), and BIM informative forums. Support from the government is desirable, but in the context of the D.R., this is not attainable yet. The players taking part in this strategy need to identify the BIM competencies required in the disciplines and courses of current curricula. An excellent example of this approach is the Matrix of BIM Roles developed by Plan BIM in Chile (Refer to Chapter 3, Section 3.3.3.2.3). BIM experience from current BIM practitioners in the D.R. could be of great help in identifying the BIM competencies needed in the Dominican construction industry.

8.4.1.6.2 Stage 2: Preparation

After the competencies are identified, it is necessary to provide education to prospect educators. In the D.R. was noted that most of the stakeholders involved in BIM education and training are self-taught. Even though these players are already making an important contribution to building the BIM capacity in the country, they require proper preparation before getting involved in Academia. Once educators get an appropriate education, they will be able to modify current modules and prepare the necessary teaching material. This stage can also be done in collaboration with other players in the industry. Throughout all this process, BIM needs to be promoted through different activities directed not only students but to current practitioners. In the D.R., this is being done mainly to raise BIM awareness with more contribution from the industry than Academia itself.

8.4.1.6.3 Stage 3: Realisation

Stage 3 consists of the delivery of the modules that have been modified to comply with BIM. It is suggested to deliver modules gradually to avoid a massive failure. This integration can be done gradually by disciplines. For instance, modify the Architecture curricula first and the move to the remainder disciplines. It can also start with senior year students who are more experienced and then go to the lower levels.

8.4.1.6.4 Stage 4: Revision

Lastly, Stage 4 consists of the assessment of the first module(s) delivered. This assessment needs to be carried out by different players. Firstly, it is essential to get feedback from the BIM learners as to the module(s) programme, learning materials provided and learning attained. Furthermore, educators need to monitor the delivery of the modules; thus, they can evaluate different aspects such as progress and performance of the students, the need for extra training/education for them, and successfulness of the module programme. In this stage, input from industry players is recommended to guide educators as to which improvements may be necessary after they carry out their assessment.

After the first attempt of integration is revised, the process can start again until attaining the final milestone. Then, the group will have the necessary capability to take further steps, such as:

- Creation of BIM-based undergraduate and master's degrees.
- Research opportunities – PhDs.

- Offer work experience opportunities to BIM learners.

8.4.2 Framework to guide the BIM implementation process in construction organisations

Developing a framework to guide the implementation of BIM in construction organisations represents a difficult task. As Ahmad, Demian and Price (2012) indicated, there is not a universal guide for implementing BIM. BIM deployment standards are not compatible with all organisations due to unique aspects such as organisational culture, size, processes, organisation's goals and objectives. Therefore, the approach undertaken to develop this framework was to provide Dominican construction organisations with an essential guide for BIM implementation. This guide can be used as a starting point for those not implementing and as a check-list for those already involved that may need further guidance (i.e. organisations in transition to implementing BIM and organisations implementing BIM).

Another difficulty in that matter is the countless factors that need to be considered for the implementation of BIM in an organisation. To overcome this issue, it was necessary to opt for a simple, yet, complete structure that could summarise these factors. For that, the structure of several hybrid frameworks was analysed, as illustrated in Table 8.3.

Table 8.3 Rationale for framework structure directed to construction organisations

Source: Mihindu and Arayici (2008); Coates (2013); Sackey et al. (2013); Panaitescu (2014)

Coates (2013)	**Mihindu and Arayici (2008)**	**Sackey *et al.* (2013)**	**Panaitescu (2014)**	**Proposed framework**
Stage 1: Approvals and control	Preparation phase	Brainstorming	Phase 1: Raising awareness Phase 2: Reasoning Phase 3: Decision making	Stage 1: Persuasion
Stage 2: Investigation and definition		Brainstorming		
Stage 3: Defining the vision		Brainstorming		Stage 2: Definition
Stage 4: Planning the execution		Concept building stage	Phase 4: Planning the implementation	Stage 3: Planning
Stage 5: Mobilising for the prototype projects	Role-out phase	Realisation	Phase 4: Planning implementation Phase 5: Implementing Phase 1 Phase 6: Implementing Phase 2	Stage 4: Implementation
Stage 6: Undertaking the prototype		Realisation Manifestation		
Stage 7: Mobilisation for the live company projects		Realisation Manifestation		
Stage 8: Undertaking live company projects using BIM	Post-implementation	Manifestation		
Stage 9: BIM implementation review		Manifestation	Phase 7: Confirmation	Stage 5: Confirmation

Based on the analysis of the above frameworks, the framework was designed containing five stages: persuasion, definition, planning, implementation and confirmation (Refer to Figure 8.8). Following will be described the steps to be followed in each stage as well as relevant information for its understanding.

8.4.2.1 Persuasion

In the Dominican Republic, the drivers for BIM adoption are BIM benefits, Competitive advantage and Pressure from external partners. The decision of implementing BIM relies on the organisation itself or the external partners if they have enough power to convince the organisation. Therefore, the framework starts with a decision-making process named *Persuasion stage*. Persuasion takes place when an individual or other decision-making unit develops a favourable or unfavourable attitude towards an innovation (Rogers, 1995).

The persuasion stage of the framework consists of three stages: assess current work process, explore BIM benefits and BIM uses/BIM challenges and risks, and identify BIM opportunities.

8.4.2.1.1 Assess current work processes

BIM cannot be efficiently adopted with traditional approaches. Therefore, organisations must perform an internal assessment of their work processes to identify which workflows and methods should be re-arranged for BIM (London *et al.*, 2008; Morlhon, Pellerin and Bourgault, 2014). Gu and London (2010) suggested the creation of work process roadmaps for this procedure.

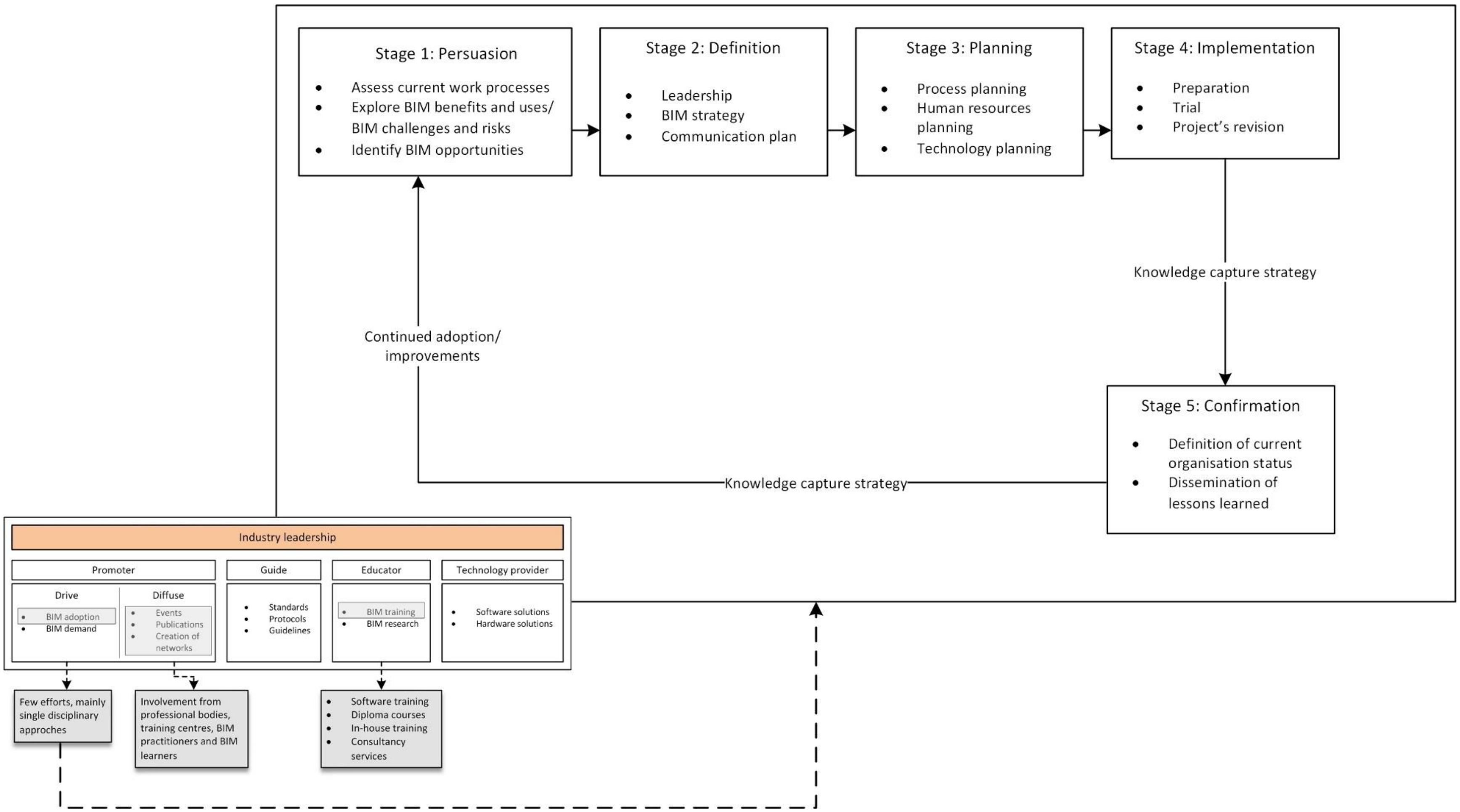


Figure 8.8 Framework to guide the BIM implementation process in construction organisations

To create work process roadmaps, organisations can take the following considerations: identify the project phases the organisation involved in; list the activities executed in each project phase; and identify the different actors involved in the activities, both internal and external, and the deficiencies of current activities. With the last step, organisations can identify the processes that require re-engineering for the adoption of BIM (Mihindu and Arayici, 2008). Identifying these areas where BIM is most needed is quite beneficial, especially when there are limited resources for the implementation (Barry, Daniel and Bleanch, 2012) (Refer to Figure 8.9).

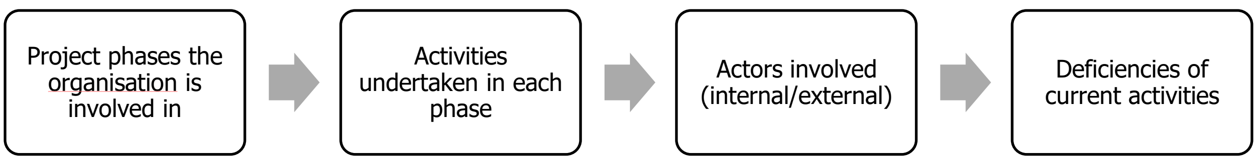


Figure 8.9 Suggested steps to assess the organisation's work processes

8.4.2.1.2 Explore BIM benefits and BIM uses/ BIM challenges and risks

At the persuasion stage, individuals and decision-making units are driven to investigate the innovation to reduce any uncertainties they may have about it in terms of their advantages, disadvantages and consequences (Rogers, 1995). Organisations need to understand the potential benefits of BIM and their use in the different stages of the project lifecycle (London *et al.*, 2008). Therefore, it is suggested to explore the benefits and different uses of BIM. Moreover, it is also essential to identify the challenges and risks its implementation implies to know what can be expected and take prior measures about it.

8.4.2.1.3 Identify BIM opportunities

After analysing their work processes and undertake an investigation of BIM with its positives and negatives aspects, the organisation can then identify the opportunities that BIM can offer. These include the benefits for the organisation and the business opportunities with their external parties and their clients. After this analysis, the organisation should be able to decide whether or not to implement BIM in their practices.

8.4.2.2 Definition

The need for an effective and clear strategy has been identified as a success factor to implement BIM (Khosrowshahi and Arayici, 2012) and attain BIM benefits (Morlhon *et al.*, 2014). If the organisation has decided to adopt BIM, the next stage consists in defining the strategy to be taken, which is named as *Definition stage*. This stage is divided into three phases: Leadership, BIM strategy and Communication plan.

8.4.2.2.1 Leadership

Any organisational change requires leadership. Organisations that decide to change deliberately must as well identify change agents that will be responsible for leading and realising the change effort (Lines *et al.*, 2015). For the implementation of BIM is recommended a top management leadership supported by other champions within the organisation (Refer to Figure 8.10).

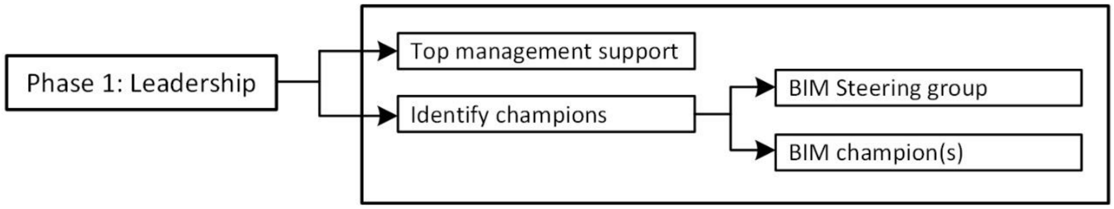


Figure 8.10 Stage 2. Phase 1: Leadership

8.4.2.2.1.1 Top management support

Top management support has been generally considered an important factor for technology implementation and innovation in organisations (Lee *et al.*, 2015; Ahuja *et al.*, 2018).

Furthermore, it is considered a relevant factor to adopt BIM in an organisation (CIC, 2013; Eadie *et al.*, 2013b; Imoudu Enegbuma *et al.*, 2014; Xu *et al.*, 2014; Ding *et al.*, 2015; Abbasnejad, Nepal and Drogemuller, 2016; Ahuja *et al.*, 2018). Organisations that have substantial top management support to adopt BIM are more likely to implement it (Xu *et al.*, 2014; Lee *et al.*, 2015). Leaders are responsible for pushing and motivating change in all the organisation in the transition to BIM (Autodesk, 2012). There is also less risk when the decision of adopting BIM in an organisation comes from senior management (Lee *et al.*, 2015). Greater involvement from the top management allows organisations to obtain more benefits from the implementation and guarantees that their members are introduced to proper changes in business processes before the implementation takes place (Ahuja *et al.*, 2016).

If top managers do not get involved in the implementation, it is probably that the planning team will not have the required resources to plan and adopt the suggested proposals. When top managers are involved, fundamental decisions to continue with the implementation are more easily made (CIC, 2013).

8.4.2.2.1.2 Identify champions: BIM champions and the creation of a BIM steering group

Top management support needs to cover not only a strategy but also the whole implementation process and day-to-day activities (Ding *et al.*, 2015). Also, senior management is required at an organisational and project level (Xu *et al.*, 2014). Due to the numerous aspects that top managers need to oversee, it is recommended to identify the most capable individuals to monitor the implementation process within the organisation. For that, two key strategies are suggested: the assignation of BIM champions and the creation of a BIM steering group.

A BIM champion is a person who has technical skills and the eagerness to guide an organisation by driving the adoption of BIM, managing resistance to change and guaranteeing that the implementation is realised (CIC, 2013). BIM champions drive the implementation of BIM at an operational level (Sackey, Tuuli and Dainty, 2013). Their role can include monitoring BIM implementation in project teams (CIC, 2013; Azzouz *et al.*, 2016), develop internal implementation planning in each department of the organisations (Panaitescu, 2014; Ghaffarianhoseini *et al.*, 2016), and build BIM education/training strategies (Kumar, 2015). On the other hand, a BIM steering group can have the responsibility of developing the BIM strategy of the organisation (CIC, 2013; Ghaffarianhoseini *et al.* 2016). The group can be compound by BIM champion(s), and individuals with knowledge and experience with BIM, which can be from top managers and stakeholders, middle managers, and technical staff (CIC, 2013).

The need for these actors will depend on the needs and size of the organisations. For instance, an SME may develop their strategy by the support of only one BIM champion. Furthermore, having these actors internally (e.g. BIM champion) is considered key in the successful adoption of BIM (Ahuja *et al.*, 2016). Nonetheless, when an organisation does not have individuals with BIM experience, an external BIM experienced party will be needed (CIC, 2013). Initial training can also be considered for these actors to keep the process internally (Mihindu and Arayici, 2008; Coates, 2013).

8.4.2.2.2 BIM strategy

For an effective BIM implementation, the BIM strategy should consider, at least, the following aspects: Vision, BIM scope, BIM uses, Cost/benefit analysis, and Implementation timeline (Refer to Figure 8.11):

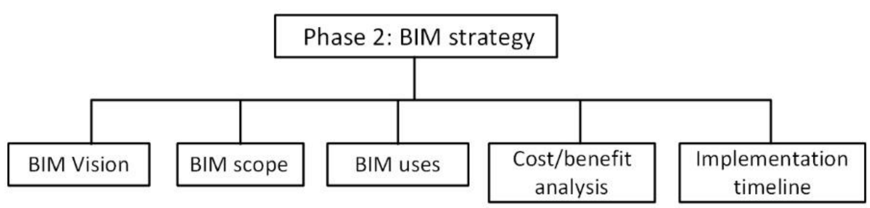


Figure 8.11 Stage 2. Phase 2: BIM strategy

8.4.2.2.2.1 Vision

Top management needs to formulate a solid vision of where the organisation is going with the implementation of BIM, what the organisation will achieve with the BIM business transformation, which are the main elements of this transformation and how this change will look like at various phases (Autodesk, 2012). The organisation's strategy will be then be developed based on the vision (Panaitescu, 2014). Even though the vision of BIM should come from top managers, nowadays it is frequent to see BIM leaders at middle management level trying to motivate high-level executives to implement BIM. When this happens, these leaders will need to define the BIM vision while looking for executive support. This action can be considered as a transitional step toward an executive-driven change. Even though there are examples of organisations that have transitioned this way successfully, this approach narrows down more comprehensive organisational BIM benefits and increments the risk of failure in the transition process (Autodesk, 2012).

8.4.2.2.2.2 BIM scope

BIM implementation can range from a complete integrated multidisciplinary BIM including online collaboration and real-time updates in every stage of the project’s life cycle to a single disciplinary approach with the creation of models for specific phases, sub-phases or activities within a phase (Gu and London, 2010). The organisation needs to take the decision of either implementing a single or multidisciplinary approach, being aware that the main benefits can only be achieved through a multidisciplinary approach (Coates *et al.*, 2010b). After this, the extent of BIM should be mapped onto the project phases the organisation is involved (Gu and London, 2010).

8.4.2.2.2.3 BIM uses

Organisations need to establish the BIM uses that will be used internally, following the defined BIM scope of the organisation (Coates *et al.*, 2010a; CIC, 2011).

8.4.2.2.2.4 Cost/benefit analysis

Even though the cost of BIM implementation is one of the main barriers of BIM adoption, there is no clear guidance on how to estimate the cost of BIM implementation. The cost is higher in the implementation process because it involves high investments such as software, hardware and training. However, this investment is reduced gradually in the use and development stages (Ahmad *et al.*, 2012).

Table 8.4 Key Performance Indicators to measure BIM benefits

Source: Suermann (2009); Coates *et al.* (2010b); Eadie *et al.* (2013a)

Author	Key Performance indicators for BIM
(Suermann, 2009)	- Quality control (rework), - On-time completion, - Cost - Safety (lost man-hours), - Dollars/unit (square feet) performed, and units (square feet) per man-hour.
(Coates *et al.*, 2010b)	- Working hours spent per project - efficiency with cost per project - Speed of Development - Revenue per head - IT investment per unit of revenue - Cash Flow - Better Architecture - A better product - Reduced costs, travel, printing, document shipping - Bids won or win percentage - Client satisfaction and retention - Employee skills and knowledge development
(Eadie *et al.*, 2013a)	- Request for information (RFIs) - Change orders - Cost (overall) - Cost of changes - Programme duration - Person's hours worked

For organisations to know the cost of implementation, it is advised to estimate how significant the investment on software, hardware and training may be to check if the organisation's resources are enough for this up-front investment. Furthermore, Key Performance Indicators (KPIs) can be selected to measure the benefits (tangible and non-tangible) (Coates *et al.*, 2010b; Arayici *et al.*, 2011) during and after the implementation process to justify the Return of Investment (ROI) (Coates *et al.*, 2010b) (Refer to Table 8.4).

8.4.2.2.2.5 Implementation timeline

An implementation timeline should also be established (Sackey *et al.*, 2013; Abbasnejad *et al.*, 2016), which will be informed by the financial resources available and the defined BIM scope and uses. The timeline consists of a general outlook of the transition plan to BIM. It should contain milestones and key objectives regarding the implementation (CIC, 2013).

8.4.2.2.3 Communication plan

A high profile communication plan should be developed internally and externally to facilitate the transition to BIM in the organisation and engage all the stakeholders (Refer to Figure 8.12). The following sections explain how the internal and external communication plan can be achieved.

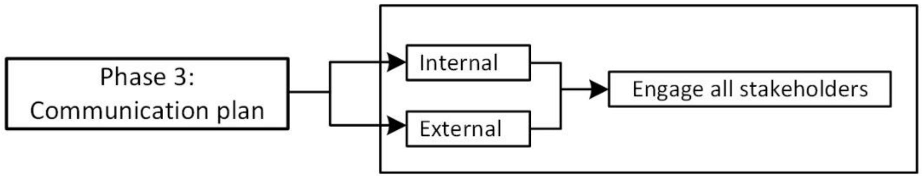


Figure 8.12 Stage 2. Phase 3: Communication plan

8.4.2.2.3.1 Internal communication plan

Top managers should inform their employees about the new vision of the organisation in terms of BIM (Ahuja *et al.*, 2016; Abbasnejad *et al.*, 2016). A high-profile communication plan is suggested to raise awareness for top-to-bottom buy-in within an organisation; thus, the organisation can transmit its goals and achievements regarding BIM inside and outside the organisation (Autodesk, 2012).

Furthermore, it can reduce resistance to change from members of the staff as they can participate in the BIM strategy by being introduced to how BIM works, how is going to affect their jobs and tasks and the benefits obtained with it (Abbasnejad *et al.*, 2016). This plan should be developed and delivered at the right time through presentations, exhibitions and demonstrations (Arayici *et al.*, 2011). Ghaffarianhoseini *et al.* (2016) further suggested activities such as workshops, seminars and posters.

8.4.2.2.3.2 External communication

Convincing partners from other organisations represent a barrier to the full implementation of BIM. Therefore, an organisation must communicate their internal strategy and new competencies to their partners; thus, they are aware of the organisation's status, and business opportunities are not missed (Haron, 2013).

8.4.2.3 Planning

After developing the BIM strategy, the organisation needs to plan the implementation of BIM within the organisation. This planning should involve the main changes which are related to processes, people, and technology (Refer to Figure 8.13).

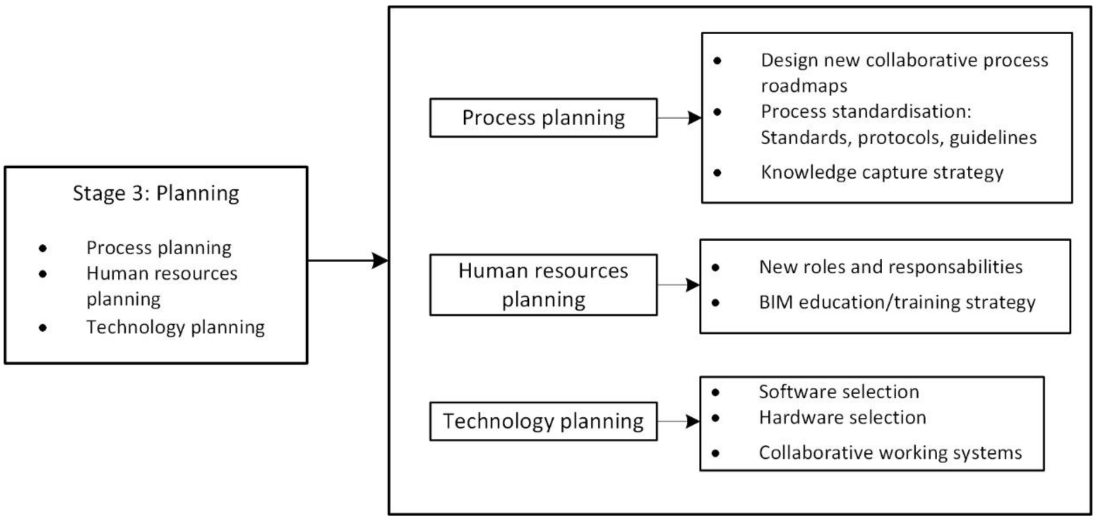


Figure 8.13 Stage 3: Planning

8.4.2.3.1 Process planning

For a successful BIM implementation, fundamental changes are necessary regarding the way of working at almost every level of a building process (Khosrowshahi and Arayici, 2012). These changes are discussed below.

8.4.2.3.1.1 Design new collaborative process roadmaps.

For process planning, organisations need to re-organise current workflows (Khosrowshahi and Arayici, 2012). New workflows and processes must be arranged and checked. New workflows and processes need to be aligned with BIM (Autodesk, 2012).

8.4.2.3.1.2 Process standardisation

Well-defined standards and processes that manage all projects and programs that determine BIM usage need to be established. Organisations can start by applying available references and guides for implementing BIM standards and best practices. Nonetheless, it is important to note that there are no standards that can respond to every organisation's situation and characteristics (Autodesk, 2012). For that, organisations may need to adapt them to project needs and local industry characteristics (Coates, 2013). Hardin and McCool (2015) suggested the creation of bespoke templates of these documents. Nonetheless, this may not be the best approach for a BIM infant country like the D.R. since it will generate a large number of templates that may include difficult inter-organisational practices. Currently, organisations implementing BIM prefer the first approach and are mainly following American and British standards (Refer to Chapter 5, Section 5.4.3.3).

8.4.2.3.1.3 Knowledge capture strategy

Construction organisations usually systemise knowledge related to "know-what" and "know-why". Nonetheless, knowledge respecting "know-who" and "know-how" tends to be omitted, from which the latter is highly relevant. Therefore, organisations must incorporate project experiences into construction business functions to achieve consistent organisation (Blayse and Manley, 2004). For effective implementation of BIM, it is advisable to create a knowledge capture strategy to acquire and retain knowledge for future BIM integration (Gu and London, 2010). Following the single source principle of BIM, this strategy can be supported by the use of an integrated knowledge database platform with information that the organisation's staff could use to record, share and enquire project support information. This database can contain non-structured data (e-mails, letters, spreadsheets, word documents, drawings, etc.) to allow knowledge capture and experience from previous projects and experienced staff (Arayici *et al.*, 2011).

8.4.2.3.2 Human resources planning

The introduction of new processes within an organisation encompasses the change of the organisation's culture, which implies risks and challenges on many areas, including the adaptability and versatility of the organisation's members (Eadie *et al.*, 2014). One of the most important considerations for a successful BIM implementation is having proper personnel. For that, the implementation plan should consider the organisational structure, the different roles and responsibilities, training and education, and how the change will be managed in the organisation (CIC, 2013).

Human resources planning should consider at least the new roles and responsibilities and the required training for these purposes.

8.4.2.3.2.1 Roles and responsibilities

As explained in Chapter 5, due to the nature of this industry, where many projects are developed by multidisciplinary and multi-organisational teams, lack of clarity on roles and responsibilities represents a key inhibitor factor for BIM adoption (Gu and London, 2010). Hence, the organisation needs to assign the new roles and responsibilities of the active BIM players in the company (CIC, 2013). These roles and responsibilities will be determined by the BIM uses established by the organisation.

8.4.2.3.2.2 BIM education/training strategy

Effective change management involves the provision of training of an organisation's staff and its stakeholders (Arayici *et al.*, 2011). After the new roles and responsibilities have been set, the organisation needs to prepare a BIM education/training strategy to build the capability of the personnel. It is recommended to develop this strategy before software acquisition (Reddy, 2012). This strategy can be developed by a BIM champion designated by the organisation, either internal or external. Then, the BIM champion needs to identify the required training for the new roles and responsibilities established in the previous stage. Assessing the current competencies of the staff can be beneficial to know where to focus on when creating the education and training required.

For successful implementation, it is necessary to provide education and training to key personnel to assure awareness of the benefits of BIM before practical implementation (Eadie *et al.*, 2015). Education and training need to be provided according to the staff's roles (Arayici *et al.*, 2011) since not everyone requires the same education/training (CIC, 2013). Therefore, it is recommended to identify the education/training requirements per staff's roles as follows:

- *Top management:* essential knowledge of BIM processes (CIC, 2013).
- *Middle management:* broad education on BIM and introductory training on software (CIC, 2013).

- *Users:* broad education on BIM and training on software knowledge (CIC, 2013). Members of the project team must have BIM-competencies such as collaboration, track record and previous experience of implementing BIM. Collaboration between disciplines is also essential for the successful implementation of BIM. If a broad training is not given to project team members, misuse or mistakes are likely to occur during the implementation because of the sophisticated software and distinctive situations part of the modelling process (Ding *et al.*, 2015).
- *Field personnel:* They need to have a basic understanding of contract language and model manipulation to undertake tasks such as tracking issues, managing changes and punch lists, commissioning, validating installation and closing out projects. They can also be trained on how to generate logistic plans, virtual mock-ups and conduct clash detection in the field (Hardin and McCool, 2015).
- *Client:* Knowledge on what their role is, what to demand, and what to control. For instance, how to produce documents such as EIR (Employer's Information Requirement) and Asset Information Requirements (AIR); and how to check the BIM Execution Plan (BEP) elaborated by the supply chain (Silverio *et al.*, 2016, 2017a).

Lastly, the organisation needs to decide whether this training is going to be delivered internally (e.g. BIM Champion or any other capable staff), or with external BIM education providers. Concerning the client, it is recommended to assign advisers or BIM consultants that instruct them on what they need to do. They can also get involved in educational activities within the organisations if necessary (Silverio *et al.*, 2016, 2017a). Figure 8.14 summarises the proposed BIM training/education strategy.

Figure 8.14 Suggested steps for BIM education/training strategy

The effectiveness of the education/training provided will be assessed on the confirmation stage (Stage 5) through the performance of the project members and project's outcomes (Silverio *et al.*, 2016, 2017a).

8.4.2.3.3 Technology planning

Organisations must develop a technology plan to analyse all the technical aspects of the implementation: Software, Hardware and Collaborative working systems.

The high investment in software and hardware has been extensively pointed out as a significant barrier to the implementation of BIM implementation (Eadie *et al.*, 2013a). Therefore, the selection of both is an essential decision for the organisation.

8.4.2.3.3.1 Software selection

Organisations need to select the necessary BIM tools/software for their BIM approach (London *et al.*, 2008; Coates *et al.*, 2010b; Arayici *et al.*, 2011b; Won *et al.*, 2013; Morlhon *et al.*, 2014; Ding *et al.*, 2015). Software selection needs to be based on the BIM uses within the organisation. The list of available BIM software packages is changing and increasing continuously. Organisations need to know that one software package can offer support multiple BIM uses but, at the same time, one software may not be enough for all their BIM goals (CIC, 2013).

It is advisable that the organisation first evaluate current software to know if they are compatible with BIM. Many organisations in the Dominican Republic are using BIM compatible software regardless they are implementing BIM or not. If that is the case of the organisation going through the implementation process, they should then understand the capability of the software in terms of BIM. Secondly, the organisation should revisit the BIM uses set as its target and evaluate which BIM software will allow them to realise these goals. After this investigation, the organisation may have a list of potential software. To make the decision is suggested to set software selection criteria. The criteria to be followed will be informed by the organisation's current situation (e.g. Budget restrictions, personnel capabilities, etc.). Nonetheless, key considerations that should not be ignored include software interoperability, since lack of interoperability represents a barrier to successful BIM adoption; availability of training; and capability of external partners (Xu *et al.*, 2014). After selecting software, it is recommended that the organisation purchase software only for the Implementation stage (trial phase) (Refer to Section 8.4.2.4.2). If software selected meet the targets, the organisation can confirm the use for further phases and projects and acquire a permanent license after the Confirmation Stage (Stage 5) (Refer to 8.4.2.5). The proposed software selection process is presented in Figure 8.15.

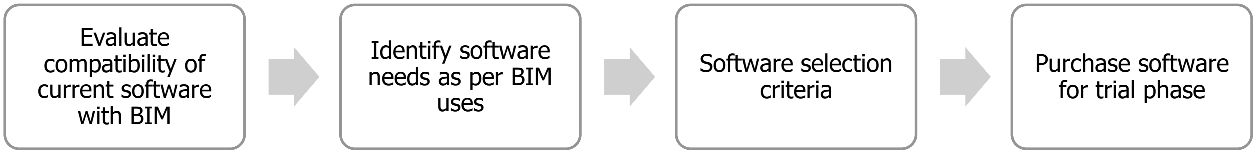


Figure 8.15 Software selection

8.4.2.3.3.2 Hardware selection

Organisations need to select appropriate hardware to support the chosen software to avoid problems and frustrations when implementing and integrating BIM within the organisation. It is fundamental to understand the hardware specifications of the devices (laptops, computers, etc.) where BIM models will be created and manipulated. Otherwise, the model and data used may become impractical. It is also essential to guarantee that the hardware supports the BIM uses that the organisation has set for the implementation (CIC, 2013). Organisations may need to either acquire new hardware or make major or minor upgrades to existing hardware. This decision will depend on current hardware conditions, the level of BIM implementation and the organisation's plan for using BIM in the future (Olatunji, 2011). The proposed hardware selection process is presented in Figure 8.16.

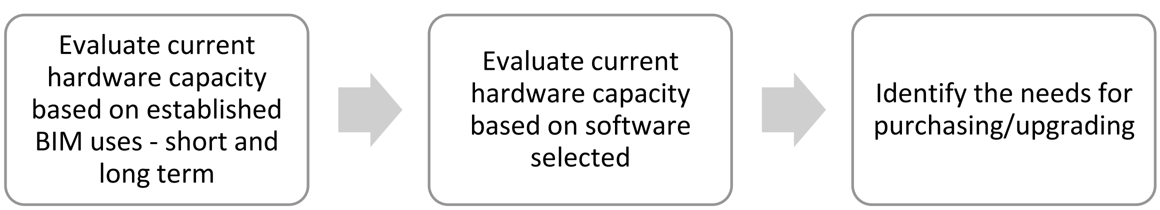


Figure 8.16 Hardware selection

8.4.2.3.3.3 Collaborative systems and data handling IT requirements

The collaborative nature of BIM and the amount of data that is managed in a BIM environment demands IT solutions which can be software-based, hardware-based or cloud-based. Organisations need to select the option that best suits their BIM uses, financial resources, etc.

- *Hardware-based:* Servers and computer networks can be used to manage the memory and space needed for BIM software. Organisations can also take security measures by purchasing backup hardware and software to prevent any data loss (Reddy, 2012).
- *Software-based:* BIM process and model management tools can be integrated into enterprise systems to deliver information and create a collaborative environment (CDE) where information is shared within the organisation and project team (Autodesk, 2012).
- *Cloud-based:* Cloud-based computing offers universal, on-demand entry to a shared collection of configurable computing resources (e.g. servers, networks, applications, devices and data) which can be accessed and discharged with minimum management or service provider interaction. Therefore, it facilitates real-time collaboration and offers project team the possibility of expanding the use of BIM from design to construction (Matthews *et al.*, 2015).

8.4.2.4 Implementation

After planning the implementation in the major areas: process, people and technology, the organisation needs to put everything into practice in the implementation stage. It is advised to undertake this stage as an experimental process through pilot projects (Mihindu and Arayici, 2008; Deutsch, 2011; Autodesk, 2012; Khosrowshahi and Arayici, 2012; Coates, 2013; Haron, 2013).

For the implementation stage, the following actions are recommended: preparation, trial and project's revision.

8.4.2.4.1 Preparation

8.4.2.4.1.1 Select projects for trial

To select pilot projects, Arayici *et al.* (2011) suggested piloting BIM on past, current and future projects as a way to test the new processes in the organisation continuously. Coates (2013) further argued that two types of pilot projects are recommended: redevelop a current project done with traditional methods to make a comparison of the old and new processes, and carry out new pilot projects to validate organisation' s new capabilities.

8.4.2.4.1.2 Time management

Time is the primary resource to carry out the pilot project(s). Time scales, as well as the goals and deliverables of the project(s), should be determined before the implementation process (Coates, 2013).

8.4.2.4.2 Trial

During the trial phase, the pilot project(s) needs to be monitored, and the results from the application of new methods and processes need to be documented through the knowledge capture strategy developed in the process planning. This way, the effectiveness and deficiencies of the BIM implementation can be assessed.

8.4.2.4.3 Project's revision

After the completion of the pilot project(s), is recommended to:

- Identify the benefits obtained from the implementation. For that, the organisation can make use of the KPIs considered in the cost/analysis;
- Identify issues in the workflows;
- Assess the efficiency of the developed strategies.

8.4.2.5 Confirmation

Lastly, in the confirmation stage, the organisation will be able to define its current status and disseminate lessons learned within the organisation for continued adoption and further improvements.

8.4.2.5.1 Definition of current organisation's status

To define the current status of an organisation concerning BIM, it is recommended to elaborate BIM manuals, confirm the new BIM uses and capabilities, and reinforce new products and business opportunities (Figure 8.17):

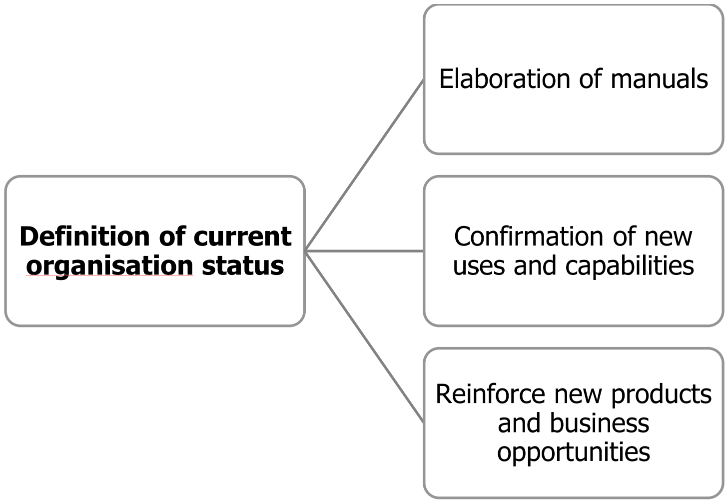


Figure 8.17 Definition of current organisation's status

The development of BIM manuals (Deutsch, 2011; Jung and Joo, 2011; Coates, 2013; Kassem *et al.*, 2014) can be either hard copy or in electronic format (Coates, 2013). The information documented in the implementation stage through the knowledge capture strategy will significantly contribute to the elaboration of manuals. These manuals can be of great help not only for further implementation in the organisation but also for the induction of new employees.

The organisation should also confirm its new BIM uses and capabilities through an internal and external communication plan, as suggested in the Definition stage (Refer to Section 8.4.2.2.3). Lastly, the organisation should also evaluate its capabilities to identify new business opportunities and make new offerings to its external partners and clients (Mihindu and Arayici, 2008; Khosrowshahi and Arayici, 2012).

8.4.2.5.2 Disseminate lessons learned

Disseminating the lessons learned in the implementation stage is vital in enabling a better implementation in the organisation. That can contribute, and is not limited, to the following:

- Update the implementation plan if evaluations indicate the need for improvement (Mihindu and Arayici, 2008);
- Evaluation of the effectiveness of the training provided and determine the need for additional training (Mihindu and Arayici, 2008; Sacks *et al.*, 2018);
- Extend BIM changes to other areas/functions within the organisation;
- Extend BIM use to new projects; and
- Integrate external stakeholders (Sacks *et al.*, 2018).

8.4.3 Framework to guide the development of a BIM mandate by government and public entities

The last framework is dedicated to the government and public sector. The Dominican government is not involved with BIM; nonetheless, the literature, worldwide examples and participants of the study suggested that government leadership is key in driving the implementation of BIM. The framework focuses specifically on guiding how a BIM mandate should be developed, an initiative highly suggested by the interviewees in terms of government leadership (Refer to Chapter 7).

According to Blayse and Manley (2004), mandatory methods have a significant influence on innovation. The implementation of BIM is more likely to be successful when is motivated by the owner; therefore, government mandates seem to be the most effective driver for its implementation (Smith, 2014c; Ismail *et al.*, 2017). A BIM mandate helps the industry to adopt BIM in an organised and regular way (Sanchez *et al.*, 2014). Government BIM mandates have a strong influence on construction companies which feel the pressure of implementing BIM to obtain future work with governmental institutions (Smith, 2014c). Lee *et al.* (2015) further explained that when a regulatory entity demands BIM, companies' eagerness to implement BIM grows regardless of BIM's practicality, general agreement among industry peers, or individual intention to adopt BIM.

BIM mandates do not only encourage practical implementation of BIM in the industry. A BIM mandate would also set the environment for knowledge providers and professionals organisations to collaborate and develop new courses to enhance the capacity of the workforce to get ready for the implementation date (Sanchez *et al.*, 2014). Consequently, if a BIM mandate is established in the Dominican Republic, the on-going process of inserting BIM in university curricula can be accelerated and structured according to what the mandate demands.

To elaborate the framework to guide the development of a BIM mandate, lessons from current BIM mandates around the world were considered. The proposed framework consists of five stages, as presented in Figure 8.18.

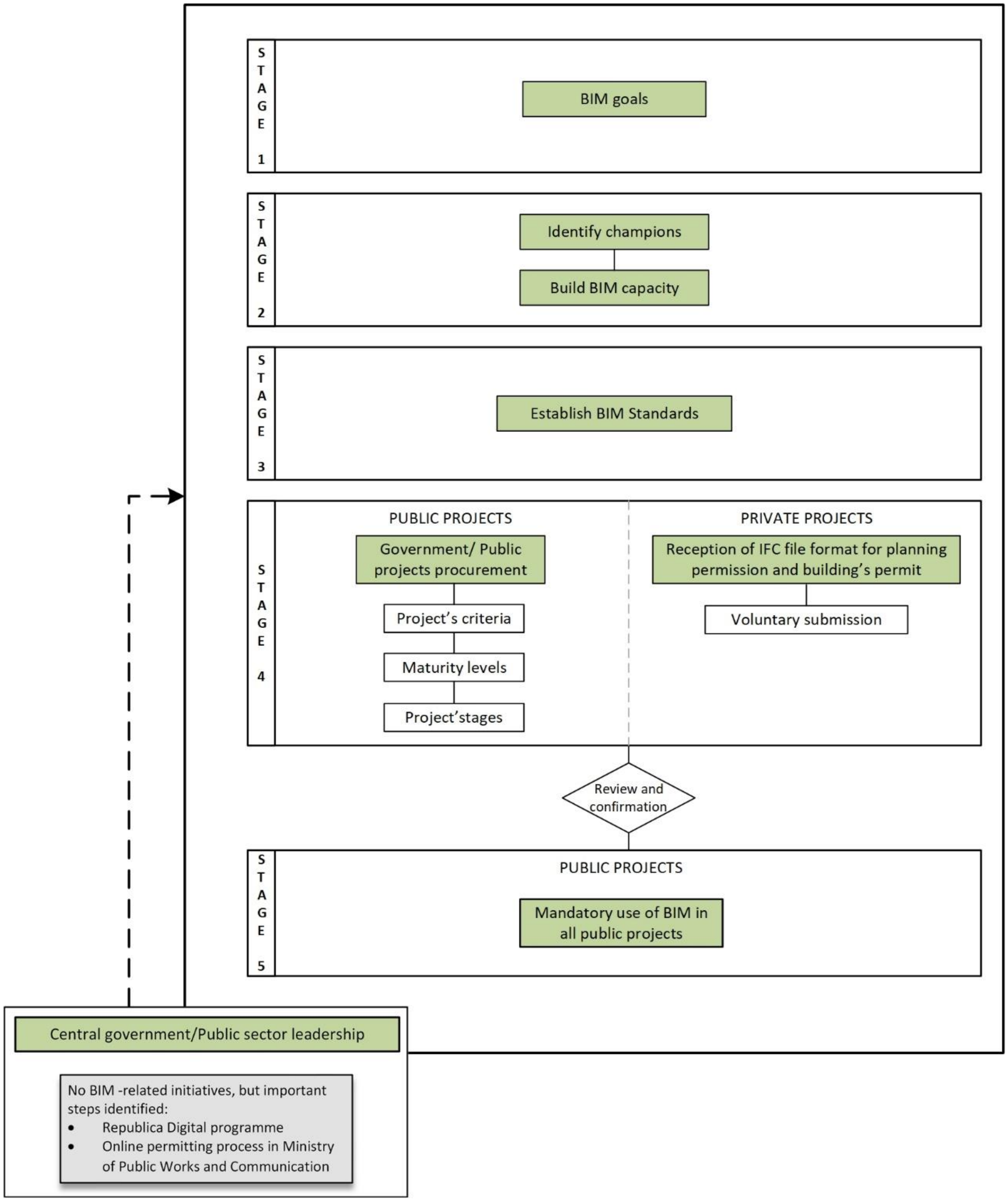


Figure 8.18 Framework to guide the development of a BIM mandate in the D.R.

8.4.3.1 Stage 1

The government/public organisation establishing the mandate needs to identify the BIM goals of the mandate (McGraw-Hill Construction, 2014b; Cheng and Lu, 2015) which will justify the reasons why BIM is necessary and which areas will be improved with its implementation. BIM goals will also set the scene of the priority and requirements of the mandate.

8.4.3.2 Stage 2

Stage 2 consists of the identification of BIM champions and building the required BIM capacity for the mandate. To manage the implementation of BIM effectively, the central government has the responsibility to identify champions for the implementation of BIM to assist the development and roll-out of a national BIM strategy (Sanchez *et al.*, 2014; Byrne, 2015). The identification of champions would allow the appointment of one or more organisations to assume the primary responsibilities of a BIM national strategy, as suggested by Wong *et al.* (2010). This organisation(s) can be either existing or new. Examples of this are the Centre for Digital Built Britain (former BIM Task Group) and the BIM Steering Committee in Singapore (Cheng and Lu, 2015).

For the D.R., it is advised to evaluate current organisations and people with the potential of managing a BIM strategy or constituting an organisation with this purpose. Potential candidates in the Dominican construction industry include representatives from the construction organisations currently involved in the implementation of BIM as well as the BIM training stakeholders and the emerging BIM communities/forums. From the public sector, the institution with more potential is the MOPC since it has already established an e-submission system and already requires 3-D models compatible with BIM for Structural analysis.

Furthermore, it is vital to build the BIM capacity of the organisation(s) in charge of the mandate and the public sector employees that will review, approve and supervise BIM projects, through the provision of BIM education and training. Currently, there is not BIM education in higher education institutions in the country. The on-going project of inserting BIM into existing curricula will be effective from 2019; nonetheless, it is one university in the capital and only includes the career of Civil Engineering. Therefore, it is recommended that the government looks for international support or partner with current BIM training stakeholders in the country. In this regard, BIM training stakeholders in the country might take the initiative of introducing BIM to governmental institutions which can then lead a partnership between both sectors. Interviewees H and I already expressed to be interested in this (Refer to Chapter 6). Furthermore, the increased number of BIM events in the country suggest that industry players may set the scene for the development of this partnership and subsequently, the provision of education and training to the public sector.

8.4.3.3 Stage 3

The next step consists in establishing the standards that will be used to regulate the mandate. It is recommended the adoption of international standards rather than creating bespoke versions for the country for two reasons. First, there is limited knowledge of BIM in the country for this purpose. As Blayse and Manley (2004) indicated, regulators must have sector-specific knowledge concerning market conditions, advanced practices and technologies, industry structure, technical infrastructure, competition and organisational capabilities. Lack of knowledge from regulators can lead to obsolescence by establishing requirements derived from existing technologies. Secondly, the adoption of international standards enables a uniform implementation of BIM across the world, which would increase the scope of BIM benefits for the Dominican construction industry. A starting point could be the analysis of the ISO 19650–1 and EN ISO 19650–2 and see how they can be adapted to Dominican construction practices (Refer to Chapter 3, Section 3.2.3.5).

8.4.3.4 Stage 4

The next step should be establishing the criteria of the mandate. BIM mandate strategies mainly consist of establishing BIM as a mandatory requirement for public projects (Porwal and Hewage, 2013). Nonetheless, they can also include private projects. An example of this approach is the Plan BIM in Chile, where the roadmap consists of milestones for both types of projects (Refer to Chapter 3, Section 3.3.3.2.1). Likewise, the proposed framework considers both types of projects to give support to current early adopters and organisations interested in BIM in the country that work either for private or both sectors. In the case of public projects, since the public sector/government act as the client/owner, several requirements need to be set up which can include and are not limited to the following (Figure 8.19):

Project's criteria. Establish minimum requirements according to the type of project (e.g. educational buildings); project size, which can be measured based on the budget (e.g. projects of 50,000,000 pesos or more); or both.

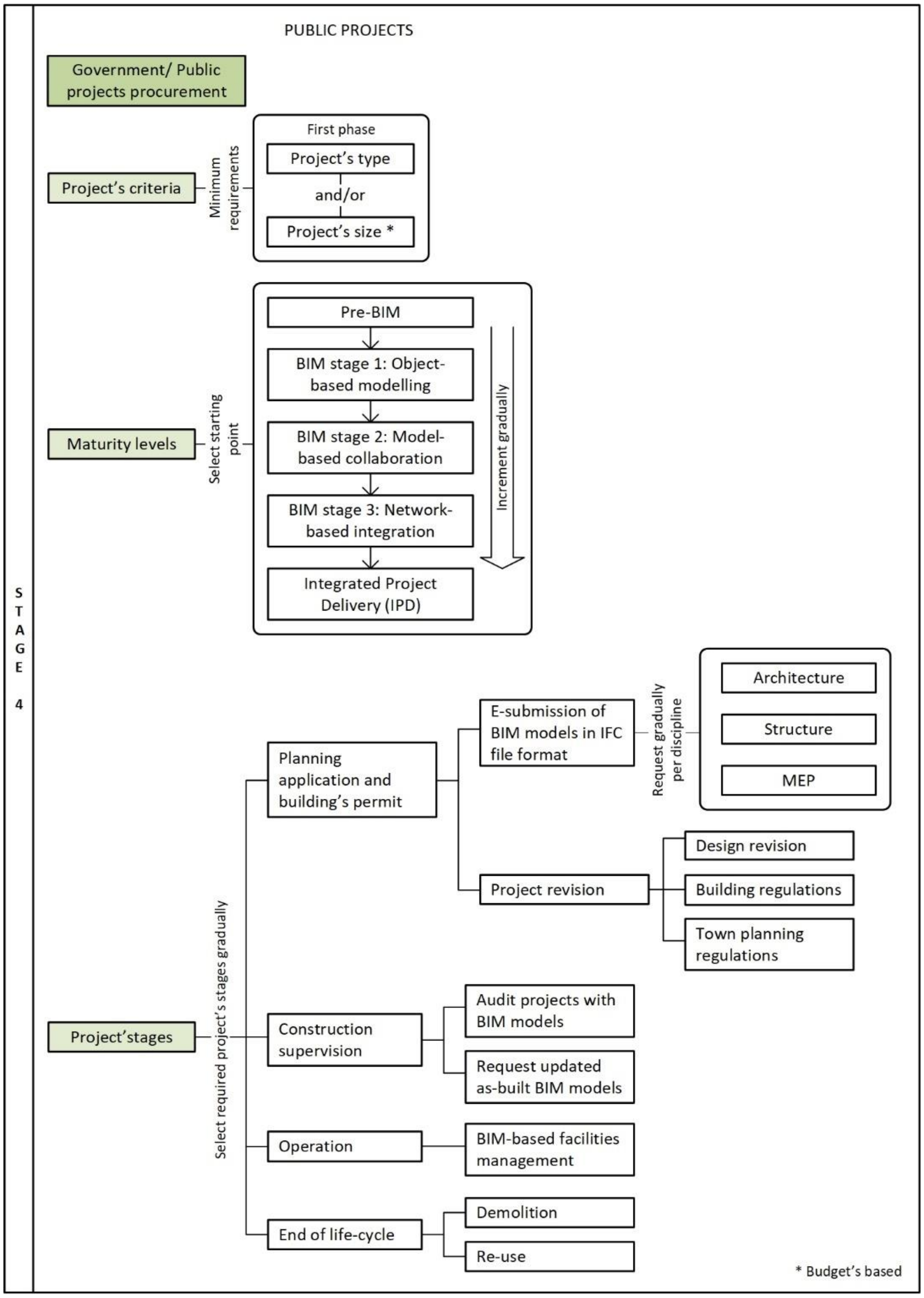


Figure 8.19 Framework to guide the development of a BIM mandate. Stage 4

Maturity levels. It is advisable to set up a BIM maturity level as a starting point for the mandate. For instance, the UK mandate establishes the implementation of BIM Level 2, following the BIM maturity model developed by Bew and Richards (Refer to Chapter 2, Section 2.2.2). Nonetheless, for this framework, the maturity levels established by Succar (2009) are suggested since they can be applied to any country. The maturity can be incremented gradually as the implementation of BIM progresses in the country.

Project stages. It is also advisable to indicate the project stages in which the implementation of BIM is necessary. Project stages will be established according to the BIM goals of the mandate, which can increase progressively:

- *Planning application and building's permit:* The implementation should start to be mandatory from the planning application and building's permit process. For that, it is suggested to establish an e-submission system as done in Singapore (Refer to Chapter 3, Section 3.2.4.1).

Software use is a crucial aspect that needs to be considered for e-submission requirements. Porwal and Hewage (2013) indicated that one primary reason why public organisations are adopting BIM is the fact that they are unwilling or even incompetent to demand the use of BIM-based on proprietary software or standards. Therefore, standards and protocols where software can interoperate are necessary to keep information open and non-proprietary. Currently, IFC is the most supported protocol among the most important BIM software providers. Furthermore, many BIM public mandates have established the use of IFC-based models (e.g. Singapore, Finland, Norway, Denmark, GSA in the USA) (Refer to Chapter 3). Hence, it is suggested to establish the use of IFC file format for the e-submission of BIM models.

Furthermore, following Singapore's BIM roadmap, an incremental change is advised by requesting the e-submission per discipline, starting for Architecture and the spreading to Structure and the remainder technical disciplines.

- *Construction supervision:* Government/public organisations will be able to supervise the projects and double-check any information through the BIM models. If changes are made, as-built BIM models will be requested and stored.
- *Operation:* Government/public organisations can manage the facilities through the BIM models if it is part of their goals. If they decide to get to this stage, additional training needs to be considered.
- *End of life-cycle:* At the moment, BIM is not extensively applied for this purpose. More research and examples of implementation are needed. Nonetheless, the framework states this is the last stage that can be considered in the mandate.

For private projects, it is proposed to enable the voluntary submission of IFC-compatible models. With this initiative, organisations that develop private projects will not have to convert their models into 2D drawings for planning permission and building's permit as they are currently doing.

The effectiveness of the mandate's requirements needs to be evaluated and confirmed according to the set BIM goals in order to pass to the next stage(s), in which the mandate is more demanding.

8.4.3.5 Stage 5

This stage establishes a more mature mandate in which the use of BIM will be set as mandatory for all public projects.

This framework proposes five stages that government and public organisations in the D.R. can follow to establish a mandate. The stages should be designed, and requirements should be established according to the government's goals with the implementation of BIM. As indicated by Sanchez *et al.* (2014), when BIM mandates have a deadline for implementation and roll-out, industry and supportive organisations get ready by setting a schedule with the different outputs and resources they need for this purpose. Hence, it is recommended to set up a BIM roadmap like in Brazil and Singapore (Refer to Chapter 3), establishing deadlines for each stage (for both public and private) and milestones within each stage. Thus, the Dominican construction industry can smoothly transition towards BIM.

8.5 Validation of the framework

Hammersley (1998) defined validity as *"the extent to which an account accurately represent the social phenomena to which it refers*". As per Creswell (2014), validity is one of the strengths of qualitative research which is built on ascertaining whether the findings are accurate from the researcher's stance, the participants or the readers of an account. A validation process had to be undertaken to ensure the developed framework is congruent with the observations from its reality (Van den Brink, 2003). The validation strategy adopted was member checking, in which the researcher requires the opinion of the participants on the findings and interpretations of the study (Creswell and Poth, 2017). Participants can comment on and suggest corrections to validate the research (Saunders, Lewis and Thornhill, 2017).

This strategy was chosen because it would allow the research to check the relevance of the findings through the people that contributed to the data collection process. Moreover, the framework was developed to address the issues identified by the interviewees. Therefore, through member checking, they would be able to identify their contribution and evaluate the appropriateness of the framework for the Dominican construction industry.

8.5.1 Description of the validation process

By the time the framework was finalised, the research could not travel to the Dominican Republic; therefore, the validation process was carried out remotely. To conduct the validation, an interactive guide was prepared in Microsoft PowerPoint, where the researcher summarised the research process, key findings and the development of the framework. The researcher piloted the guide with a colleague and the Director of studies to make sure that the guide was detailed enough for participants to understand it without the presence of the researcher. Both made comments that allowed the researcher to improve the guide before the validation process started.

Furthermore, a questionnaire was created in Google docs containing closed and open questions (Refer to Appendix 8-C). The first part of the questionnaire provided general questions to define the profile of the participants. The second part included questions related to the framework whereby participants judged its content, structure, clearness, the relevance of the information presented, and suitability for the Dominican construction industry. Lastly, participants were asked to give any recommendation to improve the framework if considered necessary.

The criterion to select the participants was to have competent knowledge of BIM to give a well-supported opinion on the subject. BIM education interviewees were potential candidates in this regard. To select participants from the interviews directed to construction organisations, the criteria were participants that had a broad knowledge of BIM and/or that they were currently implementing BIM in their work duties. The knowledge on BIM was assessed in the first part of the questionnaire by inquiring how long they have been knowledgable on BIM and if they have any formal BIM qualifications.

The potential participants were formally invited to the validation process via e-mail. The e-mail contained a cover letter (Refer to Appendix 8-B) along with the interactive guide and the link to the questionnaire. The e-mail was sent to all the participants from the BIM Education interviews and several participants from the interviews directed to construction organisations, giving priority to those that have implemented BIM or were in transition. The process of sending the invitations and receiving responses lasted two weeks. In total, 14 participants responded which met the criteria mentioned above. Table 8.5 presents the participants of the validation process, along with relevant information considered for their participation.

Table 8.5 Profile of participants of the framework validation process

Int.	Professional background	How long they have been knowledgable on BIM (years)	BIM qualifications
27	Civil Engineer	1-3	Master International BIM Management
53	Civil Engineer	4-6	
29	Architect	4-6	MSc in BIM for Integrated Construction
18	Civil Engineer	4-6	
47	Architect	4-6	
20	Architect	1-3	MSc in BIM for Integrated Construction
25	Civil Engineer	4-6	
19/A*	Civil Engineer	4-6	MSc in BIM for Integrated Construction
16	Architect	7-9	
24	Civil Engineer	4-6	
8	Architect	4-6	
C	Civil Engineer	4-6	
35	Architect	7-9	
B	Architecture Technician	1o years or more	

8.5.2 Validation results

Overall, the framework received very positive feedback. All the participants asserted that the framework was easy to understand. Furthermore, nearly all the participants (93%) considered that the information presented in the framework was relevant. Regarding their opinion as per the framework's content, pertinent feedback could be elicited. Many of the interviewees noted that the framework was very detailed and aimed to cover all the necessary aspects for the implementation of BIM in the country:

> *"The content has a clear and direct focus regarding the general aspects to take into consideration for the understanding and implementation of the BIM methodology"* - Interviewee B

In terms of the framework structure, most of the interviewees found it to be very well-structured, clear and straightforward:

> *"It provides an easy guideline to the reader, although the structure is long due to the nature of the framework, it is proper to say it is highly informative, instructive and organised. Dividing it into levels, then sections and sub-sections provide the sense of having the option to revise any enquires. Regarding the scheme, it has been presented in an interactive manner in which the reader feels the commitment to analyse it completely. As a guideline it is very specific and competent"* - Interviewee 29 from Org. 18

All the interviewees stated that the developed framework is suitable for the Dominican construction industry, as argued by Interviewee C: *"Yes, because it fits local reality"*. In addition to that, Interviewee B pointed out the potential of the framework to be used in other markets: *"Yes, it is not only for the Dominican Republic but for any country that establishes the implementation of BIM as a goal in all its domains, from education to governmental mandates".*

To conclude, interviewees that made suggestions to improve the framework provided recommendations out of the scope of work the framework and this study (Table 8.6). Nonetheless, their contribution was noted as recommendations for further research (Refer to Chapter 9, Section 9.6.3).

Table 8.6 Recommendations for the framework

Interviewee	Recommendations for the framework
Interviewee 23, Org. 12	*"Presenting the Benefits Vs Challenges would be beneficial."*
Interviewee 25, Org. 16	*"Further insight into the collaboration among major stakeholders might be helpful."*
Interviewee 24, Org. 16	*"Work on national regulations to integrate BIM."*

8.6 Summary

This chapter discussed the development of the framework to facilitate the implementation of BIM in the Dominican construction industry. The comprehensive framework is composed of three frameworks directed to the key players that can drive the implementation of BIM in the Dominican construction industry. The framework proposes strategic planning that each player can follow to drive the implementation of BIM successfully. Each framework establishes its players along with their aim as follows:

- Academia: Framework to guide the integration of BIM into university curricula.
- Construction organisations: Framework to guide the BIM implementation process in construction organisations.
- Central government/public sector: Framework to guide the development of a BIM mandate.

The framework to guide the integration of BIM into university curricula in Academia consists of four stages: (1) Strategy, (2) Preparation, (3) Realisation, and (4) Revision. The framework to guide the BIM implementation process in construction organisations contains five stages: (1) Persuasion, (2) Definition, (3) Planning, (4) Implementation, (5) Confirmation. The framework to guide the development of a mandate in the central government/public sector is composed of five stages. Stage 1 proposes the establishment of BIM goals. Stage 2 consists of the identification of champions to appoint organisations and build the BIM capacity of the people involved. Stage 3 consists of the establishment of BIM standards for the mandate. Stage 4 comprehends the criteria to mandate BIM gradually in public projects. This stage also establishes the voluntary submission of IFC-compatible models for the planning permission and building's permit of private projects. Stage 5 establishes the mandatory use of BIM for all public projects.

To conclude, the framework was validated with the participation of 14 interviewees. After the validation process, the final objective of this study "To develop and validate a framework to facilitate the implementation of BIM in the Dominican construction industry", could be achieved.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction

This chapter presents how the research objectives were achieved. It also discusses the key findings and beneficiaries of the research and the contribution to the body of knowledge. To finalise, it provides recommendations for industry practitioners, government and academics.

9.2 How the research objectives were achieved

As presented in Chapter 1, Section 1.3, the aim of this research is to develop a framework to facilitate the implementation of BIM in the Dominican construction industry. To achieve this aim, six objectives were established. Details on how each objective was achieved are provided below:

Objective 1: To critically analyse the concept of Building Information Modelling (BIM) and emerging technologies related to its implementation.

RQ1: What are the prevailing approaches underpinning the implementation of BIM in respect to both process and technology?

This objective was achieved through a comprehensive literature review which included multiple sources such as journal articles, conference papers, books, reports, white papers, magazines, and web pages in the context of the topic. The literature review allowed the understanding of the concept of BIM, its relevance in the construction industry and other important concepts such as BIM dimensions, BIM maturity levels and

OpenBIM. Moreover, the review focused on the most relevant emerging concepts, processes and technologies related to BIM from which Industry 4.0, Blockchain, Internet of Things (IoT), Big data, Digital Twin and Artificial Intelligence were studied. Lastly, the review emphasised the need for open standards for the implementation of all these technological advancements in combination with BIM.

Objective 2: To investigate BIM global implementation initiatives to identify the critical enabling factors for country-wide BIM implementation.

RQ2: How has BIM been implemented in global construction markets, and what are the critical enabling factors for country-wide BIM implementation?

This objective was achieved with a literature review on the implementation of BIM in different countries around the world. For that, it was considered to study the BIM initiatives and players that have driven the implementation of BIM in early and late BIM adopter countries. The early BIM adopters included the United States of America, Finland, Denmark, Norway, United Kingdom and Singapore. On the other hand, the late BIM adopter countries encompassed Hong Kong, China, Brazil, Chile and Mexico. Similarly to the previous literature on BIM, this literature review included a wide range of sources, from journal articles to web-pages in the context of the topic. It is important to note that non-academic sources were highly used in the study of BIM in Latin America due to the limited amount of academic references in the subject in these countries. The diverse initiatives to drive the implementation of BIM, as well as the players involved, allowed the identification of the critical enabling factors for country-wide BIM implementation: Central Government and public sector leadership, Academia leadership, Industry leadership and Global BIM influence. Lastly, the chapter provided an overview of the information available about BIM in the D.R. before this research.

Objective 3: To critically appraise and document the BIM awareness and implementation in the Dominican construction industry.

RQ3: What is the status of BIM in the Dominican construction industry in terms of awareness and implementation?

This objective was achieved by the analysis of qualitative data from the interviews directed to construction organisations in the preliminary and main study, which revealed the following:

- BIM awareness among the participants from all the construction organisations.
- The status of BIM implementation in the country: Participant organisations were classified into organisations that do not implement BIM, organisations in transition to implementing BIM and organisations implementing BIM. From organisations that do not implement BIM relevant information regarding BIM could be elicited, such as reasons why BIM is not implemented, openness to implementing BIM, and potential drivers that would encourage its implementation. In organisations in transition to implementing BIM and implementing BIM, important information could be drawn, such as drivers that motivated the implementation of BIM, adopted BIM implementation strategies, and issues affecting their current involvement with BIM. In organisations

implementing BIM aspects such as the scope of the implementation of BIM, adoption of BIM standards and achieved benefits were explored.

Objective 4: To explore and document the presence of BIM Education in the country

RQ4: What is the status of BIM education in the Dominican Republic?

This objective was achieved through the investigation on the subject and the analysis of qualitative data elicited from the interviews related to BIM education.

The study of BIM education in the country emerged from the preliminary study and the literature review. In the preliminary study, lack of BIM skilled personnel was identified as an important challenge to BIM implementation in the country. Moreover, two initiatives related to BIM education were identified: a training centre teaching BIM concepts in a software course and the interest of integrating BIM into a university curriculum. The literature review also indicated the importance of BIM education in facilitating the implementation of BIM in a country. The key findings on this topic were: Shortage of BIM experts, Lack of BIM education (Presence of BIM training), Dissemination of BIM knowledge in the country and Plans on BIM Education and training.

Objective 5: To identify and document the challenges hindering the implementation of BIM in the Dominican construction industry.

RQ5: What are the challenges hindering the implementation of BIM in the Dominican construction industry?

This objective was achieved through the analysis of the qualitative data obtained from the main study. In response to the question *"Which challenges do you think hinder the implementation of BIM at a national level?",* interviewees that participated in the interviews directed to construction organisations and the BIM education interviews, opined about which challenges affect the implementation of BIM in the country from their perspective as professionals within their role(s) but also from their perspective as part of the Dominican construction industry. The challenges identified were categorised as follows: Inter-organisational/Environmental, Educational, Economic, Cultural and Standardisation challenges.

Objective 6: To develop and validate a framework to facilitate the implementation of BIM in the Dominican construction industry.

RQ6: Which strategies can be set out to propel the implementation of BIM in the Dominican construction industry?

The interpretation of the entire data collection and the literature review carried out throughout this study led to the development of the framework to facilitate the implementation of BIM in the Dominican construction industry. The result was a comprehensive framework that contains three hybrid frameworks directed to the key players that can drive the implementation in the Dominican Republic: Academia, Construction organisations and the Central government and public sector. The framework was validated through member checking with the participation of 14 interviewees.

9.3 Key findings

The key findings of this research have been identified as follows: (A) Identification of the critical enabling factors for country-wide BIM implementation, (B) Status of BIM in the Dominican construction industry, (C) Presence of BIM education in the country, (D) Challenges hindering the implementation of BIM in the Dominican construction industry, and (E) Initiatives to propel the implementation of BIM in the Dominican Republic.

A. Identification of critical enabling factors for country-wide BIM implementation

The literature review on BIM implementation around the world revealed the critical enabling factors for country-wide BIM implementation: Central government and public sector leadership, Academia leadership, Industry leadership and Global BIM influence. The most robust initiatives towards BIM implementation come from the Central government and public sector. Due to their power, when they lead the implementation, different players from the public sector, Academia and the industry respond consequently, which enable BIM implementation and diffusion within a country. Academia contributes significantly to the implementation of BIM with the provision of education, research and promotion of BIM through educational activities. These initiatives can be either propelled by the government or start by their own motivation. Industry players are also of great help in initiating and propelling the implementation of BIM in a country mainly through adoption and demonstration of good practices. The collaboration among these players is key in driving and spreading the implementation of

BIM at a country level. Global influence has also been identified as relevant to the implementation of BIM in a country for the demonstration of good examples and the opportunities for international collaboration to enhance current approaches.

B. Status of BIM in the Dominican construction industry

- Findings corroborate that the implementation of BIM is in an infancy stage; therefore, the country is considered a BIM infant country. A BIM infant country is a country whose construction industry does not develop any project that is BIM; however, it is interested in implementing BIM in the future (Rogers *et al.,* 2015). This interest was confirmed by industry practitioners already in the journey of BIM implementation, those interested in BIM and the professionals related to the provision of BIM knowledge, training and education.
- The reasons as to why Dominican construction organisations are not implementing BIM were categorised as intra-organisational and inter-organisational. Intra-organisational reasons include Lack of BIM knowledge, Resistance to change, BIM is perceived as complex and "BIM is not suitable for our projects". In contrast, inter-organisational reasons include lack of supply chain buy-in.
- BIM benefits, competitive advantage and pressure from external partners were identified as the drivers to BIM implementation in the Dominican construction industry. The first two were identified by organisations that are not implementing BIM; whereas the three of them were identified by organisations in transition to implementing BIM and organisations implementing BIM.

- Overall, organisations involved with the implementation of BIM are adopting deficient strategies to implement BIM. The plans are developed "on the go", with limited planning. They mainly focus on the provision of software training, from which the Autodesk software Revit is the most predominant. Furthermore, training is primarily provided to Architecture personnel.
- The implementation of BIM is mainly realised intra-organisationally and at a disciplinary level, where Architecture design prevails.
- The standardisation of BIM processes is mainly kept to file and model naming. There is a significant influence of American standards for these purposes. The non-use of standards was also noticeable.
- Benefits obtained from the implementation of BIM include Benefits for the client, Design benefits, Construction benefits, Improved workflow and Organisation's profitability, which suggests the implementation of BIM is being explored mainly in the design and construction phase.
- Lack of supply chain buy-in was identified as an important factor that hinders the implementation of BIM in Dominican construction organisations. It was first recognised as one of the reasons why organisations do not implement BIM. Moreover, it was perceived to be an obstacle for the organisations implementing BIM to broaden the scope of their current implementation. Lastly, this factor was also reported as the cause of several deficiencies in the current implementation of BIM in organisations implementing BIM and the transition process of the organisation in transition to implementing BIM.

C. Presence of BIM education in the country

This study revealed four key findings that provide an indication of the current status of BIM Education in the country. These are Shortage of BIM experts, Lack of BIM education (Presence of BIM training), Dissemination of BIM knowledge in the country and Plans on BIM education and training.

- A few professionals are making an effort to build BIM capacity in the construction industry, but most of them have not received formal education and are autodidact. These efforts could be counter-productive if the knowledge delivered is not appropriate. Therefore, there is a need for BIM education and proper BIM training in the country.
- Hitherto, only BIM training is delivered in the country with an emphasis on software skills. Current BIM training is prone to expand because BIM training stakeholders are entirely committed to their work and want to explore further areas for teaching.
- BIM awareness is being increasingly raised through various BIM-related educational events. They have included the participation of universities, BIM training stakeholders and professional bodies and a BIM informative forum, which is also involved in delivering information through social media platforms.
- A distinguished university in the capital of the country has taken the first steps of inserting BIM into university curricula. The efforts are in two complementary subjects but represent an important start for BIM education in the country.

D. Challenges hindering the implementation of BIM in the Dominican construction industry

This study revealed a myriad of challenges hindering the implementation of BIM in the Dominican construction industry, which were categorised into the following: Inter-organisational/Environmental, Educational, Economic, Cultural, and Standardisation challenges.

- Inter-organisational/Environmental challenges: The implementation of BIM in the country is profoundly affected by the lack of government support and lack of client demand. The Dominican government has not expressed any interest regarding the implementation of BIM. The lack of client demand also affects organisations because their motivation for implementing BIM might decrease if the government or a client does not require it. Based on these findings, it can be inferred that the implementation of BIM in the D.R. is mainly propelled by the own motivation of construction organisations.
- Educational challenges: These include not only the lack of BIM education, which is a problem even present in more developed BIM countries than the D.R., but also the deficiencies of the current education for disciplines related to the construction industry. Lack of BIM education is reflected in the absence of proper education in higher education institutions in the country. Other aspects that contribute to this problem include lack of BIM knowledge among professionals, lack of BIM knowledge among academics, lack of BIM experienced professionals,

and the focus on software skills on current BIM education approaches. On the other hand, the deficiencies in construction-related courses encompass the inadequate approach in teaching students how the industry works in practices: old-fashioned curricula that do not respond to current needs, limited knowledge in construction and finance, and lack of integration among construction disciplines.

- Economic challenges: These challenges consider two aspects. Firstly, the high investment on BIM which includes investment in software, hardware and training. Secondly, the financial situation of the construction organisations, which includes the lack of financial capacity in most of the construction organisations in the country and the unwillingness to invest in innovation. This last challenge is highly related to the size of the organisations, which constitute the majority of construction organisations in the Dominican Republic (more than 81.83%) (Refer to Chapter 5, Section 5.2).
- Cultural challenges: These challenges encompass the characteristics and way of working of the Dominican construction industry. These include technological backwardness of the Engineering field, lack of collaboration, the traditional way of working, lack of planning, lack of transparency, insufficient provision of project's information, and habit of not meeting standards. They also encompass the negative attitudes towards BIM from Dominican construction professionals which include resistance to change and the opinion that "BIM is not a priority for the country".

- Standardisation challenges: These include lack of a BIM mandate, lack of standards and regulations in the Dominican construction industry, deficient systematisation in construction governmental institutions, and non-existence of BIM standards in the country.

E. Initiatives to propel the implementation of BIM in the Dominican Republic

Interviewees also contributed to the study by proposing different initiatives to drive the implementation of BIM in the country, which were categorised into the following: Provision of BIM education, Government leadership and BIM diffusion in the industry.

- The suggestions on the provision of BIM education include BIM education through higher institutions, BIM training, BIM education events, educate private clients, educate academics and elaboration of a BIM education plan by Academia. The establishment of mandatory education by professional bodies to update current professionals was also suggested.
- In terms of government leadership, participants proposed a BIM mandate, the creation of BIM regulations, the development of an agenda or strategic plan, the use of BIM in governmental institutions, regulate professionals’ salaries and the creation of a BIM institution.
- Lastly, BIM diffusion in the industry was proposed in terms of the potential players that can support this action, which include BIM adopters, BIM-centred organisations and professional bodies/industry associations.

9.4 Beneficiaries of the research

The beneficiaries of this research include individual practitioners, construction organisations, Academia players and governmental and public institutions. The results of this study will contribute to the following aspects:

- To assist individual practitioners and construction organisations interested in implementing BIM by providing them with a detailed, yet, simple guidance of the strategies they need to follow for a successful implementation of BIM.
- To assist current BIM adopters in improving their current approaches to BIM implementation.
- To guide academic institutions on how to develop BIM education plans for the integration of BIM into university curricula.
- To give recommendations to governmental and public institutions on what to consider when developing a BIM mandate.
- To increase awareness in the Dominican construction industry about their current status of BIM and illustrate how they can move forward to spread the implementation of BIM in the country.

9.5 Contribution to the body of knowledge

This current research has contributed to the body of knowledge by bridging an important knowledge gap. This research identified that there is a lack of research about the implementation of BIM in the Dominican construction industry; therefore, the status of BIM implementation in the DR is unknown. This study bridged this research gap by collecting primary data from Dominican construction organisations and construction professionals to report findings related to BIM awareness, BIM implementation, presence of BIM education and challenges to implementing BIM in the Dominican Republic construction industry.

One significant contribution of this research was the identification of the critical enabling factors for country-wide BIM implementation through the review of literature on BIM implementation around the world. The studied patterns of the implementation of BIM in different countries identified Central government and public sector leadership, Academia leadership, Industry leadership and Global influence as critical enabling factors for country-wide BIM implementation.

Findings have also emphasised the importance of collaboration to enable country-wide BIM implementation. Collaboration can be dual (e.g. Academia and the industry or Central government and Academia). Nonetheless, the ideal collaboration for a successful BIM implementation should be between the Central government and public sector, Academia and the industry, which constitutes a tripartite collaboration. Global influence and international collaboration between any of these players can also give significant benefits to a country and the development of BIM worldwide.

This research also developed a framework to facilitate the implementation of BIM in the Dominican construction industry. The interpretation of the entire data collected suggested the need to create a comprehensive framework that consists of three hybrid frameworks directed to the key players that can drive the implementation of BIM in the country: Academia, construction organisations and the Central government and public sector. Each framework has a distinctive aim and provides guidance as to how each player can achieve its key role:

- Academia: Framework to guide the integration of BIM into university curricula, developed in four stages.
- Construction organisations: Framework to guide the BIM implementation process in construction organisations, developed in five stages.
- Central government/public sector: Framework to guide the development of a BIM mandate, developed in five stages.

The validation process of the framework demonstrated that practitioners and BIM experts in the country agreed that the framework is suitable for the Dominican construction industry. This framework serves as a starting point for the implementation of BIM in this infant country. As the implementation of BIM progresses in the country, other strategies would be needed.

Outputs of this research encompass the publication of two conference papers *"BIM Education Framework for Clients and Professionals of the Construction Industry"* (Silverio *et al.*, 2016) and *"Building Information Management (BIM) education in the Dominican Republic: An empirical study"* (Silverio *et al.*, 2017b). The journal article *"BIM Education Framework for Clients and Professionals of the Construction Industry"* (Silverio *et al.*, 2017a), which is an extended version of the first conference paper, was also published.

9.6 Recommendations

This research has provided information related to the status of BIM in the Dominican Republic. The non-implementation and current BIM approaches were evaluated through the participant construction organisations. BIM education was explored through stakeholders from Academia and the industry. Also, a framework has been developed offering guidance to key players in the country (i.e. Academia, construction organisations, and the Central government and public sector) to drive the implementation of BIM according to their roles. Hence, recommendations for academics, industry and government have been put forward to provide guidance for further improvement and research, as follows:

9.6.1 Recommendations for industry practitioners

To enable the successful implementation of BIM in the Dominican construction industry is necessary to increase its implementation and diffusion. Guided by the interviewee's opinions in that matter (Chapter 7, Section 7.7), the following recommendations have been proposed:

- It is recommended the creation of BIM-centred organisations to diffuse BIM in the Dominican construction industry. Steps towards this initiative have been taken with the creation of the BIM forum in which the research is a member. This group is currently small and only joins professionals interested in the subject. The creation of more groups of this type, with the involvement of more industry players, would have a more significant effect in spreading BIM knowledge and BIM implementation throughout the whole industry.

- It is also recommended that professional bodies get involved in the diffusion of BIM since their scope of action is more extensive than any other industry player in the Dominican construction industry. It has been presented how the Professional Body A has hosted BIM events to spread BIM awareness. However, the participation of more professional bodies and the inclusion of more ambitious initiatives (e.g. creation or engagement with BIM-centred organisations) would attain greater benefits.
- To encourage the implementation of BIM in construction organisations, it is recommended that current BIM adopters promote their vision towards BIM and diffuse examples of good practice and successful projects.
- This research also demonstrated that industry players in the Dominican construction industry are quite active in propelling the implementation of BIM in the country. It is recommended that they continue joining forces to have more influence in the industry. Nonetheless, to avoid ineffective support from these players as pointed out by Wong *et al.* (2009), government support should be sought. It is advised that they formally introduce and propose the implementation of BIM to the government. The Ministry of Public Works and Communications comes into view as the most receptive entity in this regard.
- This study also illustrated that the Engineering field is lagging on BIM and technology implementation compared to the Architecture field. Hence, it is

recommended to give special attention to this field in any initiative related to BIM implementation to increase the awareness, interest and implementation levels in this field.

9.6.2 Recommendations for the government

- Business models and processes implemented in the Dominican construction industry might not align entirely with BIM. Hence, it is recommended that the government analyses BIM from the perspective of current practices and standards before establishing any initiative towards BIM.
- The importance of the collaboration between the government, industry and Academia to drive the implementation of BIM in a country has been presented. To enable BIM government leadership in the Dominican Republic, it is recommended that representatives from the government cooperate with the already active industry and academic players since they are more knowledgeable in the subject and are currently the main drivers of BIM in the country. These are construction organisations, industry professionals, BIM training stakeholders, Professional bodies and BIIM-centred organisations.
- To propose any BIM initiative (i.e. BIM mandate as suggested in the framework), it is recommended that government players acquire a thorough understanding of what BIM is and what its implementation implies. Current means available in the country for this purpose are the BIM training stakeholders from the Industry and Academia, and BIM adopters. BIM education and training programmes, as well

as knowledge sharing activities among these players, can be realised through a tripartite collaboration.

- In terms of the necessary standards for the implementation of BIM, it is recommended the adoption and adaptation of international standards into Dominican construction practices. This approach is suggested for two important reasons. First, the current lack of experience and knowledge of BIM in governmental institutions may result in deficient and incompetent standards. Second, the use of international BIM standards (e.g. BS EN ISO 19650-1, BS EN ISO 19650-2) would provide more opportunities for the Dominican industry internationally as BIM practices could be aligned to how BIM is implemented in other countries.

9.6.3 Recommendations for academics and further studies

- This research studied the status of BIM in the country through gauging the BIM awareness and implementation in construction organisations through their representatives, and the BIM Education through professionals involved in BIM educational activities. Further studies could consider studying the implementation of BIM at a project level when the implementation of BIM in the country is more spread and advanced.
- There is an opportunity for further research in governmental entities of the D.R. Studies on how BIM standards could be implemented can be beneficial.

- There is a breadth to develop frameworks to guide the implementation of BIM in construction organisations based on the size of the organisation and type of work. Other aspects such as collaboration among major stakeholders, and 'benefits vs challenges' analysis could be considered as suggested in the framework validation.
- The framework is expected to be used by the players is being directed to: Central government/public sector, Higher Education Institutions (Academia), and the construction organisations (Industry). Hence, it would be beneficial to test the framework in the above domains to establish its practical validity.

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APPENDICES

Appendix 4-A. Cover letter for interviews

[redacted]

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DATE/FECHA: ____________

DECISION SUPPORT TOOLKIT TO IMPLEMENT BIM IN THE DOMINICAN REPUBLIC/DESARROLLO DE HERRAMIENTAS DE APOYO PARA IMPLEMENTAR BIM EN LA REPUBLICA DOMINICANA

Information Sheet/Hoja de información

Querido participante potencial,

Mi nombre es ANA KARINA SILVERIO RODRÍGUEZ y soy una candidata de DOCTORADO EN FILOSOFÍA (PhD) de la Universidad de Wolverhampton, trabajando bajo la supervisión de la Dra. Subashini Suresh y los supervisores Dr. David Heesom y Dr. Renukappa Suresh. Como parte de mi programa, estoy llevando a cabo un estudio acerca de la implementación de BIM en la República Dominicana, país que ha tenido un alto progreso en los últimos años el ámbito de la construcción, pero que aun así necesita la implementación de métodos más organizados y efectivos para que los beneficios obtenidos en este sector sean mayores. Es por esto que este estudio propone la implementación de BIM que es un nuevo método de desarrollo de proyectos en el que se involucra el uso de software interoperables; la colaboración de todos los participantes de los proyectos, incluyendo al cliente por medio de diferentes herramientas tecnológicas; y el seguimiento de estándares y protocolos con el objetivo de manejar toda la información relacionada al proyecto de manera organizada y fluida para así poder monitorear el proyecto desde su concepción hasta su finalización y etapas posteriores que puedan presentarse.

En la actualidad BIM está siendo implementado principalmente en países desarrollados pero su implementación promete extenderse de manera rápida en los próximos años. Es por esto que es recomendable que desde ahora en nuestro país se vaya conociendo de qué trata BIM y los beneficios que ofrece para que así organizaciones del área de la construcción, profesionales y clientes se interesen y se preparen a tiempo para poder implementarlo.

El principal objetivo de esta investigación de Doctorado es desarrollar herramientas que ayuden y guíen en la implementación de BIM en el país y que estas herramientas puedan ser usadas en otros países en vías de desarrollo si es posible. Para ello es necesario investigar cómo se trabaja en el país en el área de la construcción; los mayores problemas que se presentan en este sector; como estos pueden ser solucionados; que tan avanzado está el sector en términos tecnológicos, de innovación, etc.; y luego evaluar los niveles de conocimiento de BIM en el país y ver si hay alguna evidencia de implementación de BIM en el país, tanto en práctica como en educación. Toda esta información será recolectada por medio de entrevistas a profesionales del área de la construcción en el país.

Luego de esta breve introducción, me gustaría formalmente invitarle a participar en este proyecto de investigación pues debido a su formación y ocupación usted ha sido considerado como una persona significativa para el mismo.

Si está de acuerdo en participar, a usted se le pedirá:

- Participar en una entrevista conmigo (aproximadamente de 45 minutos de duración) para responder preguntas relacionadas a la manera en que ud. y/o la compañía a la que pertenece trabaja en el área de la construcción. Las preguntas serán específicas del tema y no de carácter personal y a usted no se le pedirá revelar ninguna información la cual su organización podría considerar como sensible y de no divulgación para el público. Usted está en la libertad de no responder algunas preguntas si lo encuentra necesario.
- Completar el formulario de consentimiento anexo y entregármelo.

Con el consentimiento de los entrevistados, las entrevistas serán grabadas y luego transcritas en un computador. Usted puede revisar, editar o borrar los transcritos y grabaciones de su entrevista, si lo desea. Las grabaciones serán destruidas luego. Sus respuestas serán tratadas como confidenciales y los transcritos en el computador no contendrán referencias de ninguna persona (incluyendo usted) u organizaciones. Dichas referencias serán reemplazadas por códigos conocidos solo por mí y mi grupo supervisor y toda la información será almacenada de manera segura.

Una vez completado, un resumen de los resultados estará disponible al finalizar el año académico. Si usted desea obtener una copia de esos resultados, por favor, provea sus detalles de contacto. Tenga en cuenta, por favor, que toda la información colectada en esta investigación será almacenada seguramente y destruida luego de que la tesis de la misma sea entregada. Mi supervisor y yo seremos las únicas personas que tendremos acceso a esta información.

Gracias por su tiempo en considerar esta invitación y, si usted acepta participar en esta investigación, me gustaría extenderle mis gracias personales. Su contribución es apreciada en gran manera.

____

ANA KARINA SILVERIO RODRIGUEZ

Appendix 4-B. Sample Consent form for interviews

SAMPLE CONSENT FORM FOR INTERVIEWS

MUESTRA DE FORMULARIO DE CONSENTIMIENTO PARA ENTREVISTAS

ANA KARINA SILVERIO RODRIGUEZ

DECISION SUPPORT TOOLKIT TO IMPLEMENT BIM IN THE DOMINICAN REPUBLIC/DESARROLLO DE HERRAMIENTAS DE APOYO PARA IMPLEMENTAR BIM EN LA REPUBLICA DOMINICANA

Consent Statement/Declaración de consentimiento

- I agree to participate in the above research project and give my consent freely.
- Estoy de acuerdo en participar en el Proyecto de investigación señalado anteriormente y doy de manera libre consentimiento.

- I understand that the project will be conducted as described in the "Information Sheet", a copy of which I have retained.
- Entiendo que el Proyecto será conducido como es descrito en la "Hoja de información", copia la cual tengo en mis manos.

- I understand that I can withdraw from the project at any time and do not have to give a reason for withdrawing.
- Entiendo que me puedo retirar del Proyecto en cualquier momento y no tengo que dar explicación del porqué.

- I consent to participate in an interview with the researcher.
- Concedo participar en una entrevista con el investigador.

- I understand that my personal information will remain confidential to the researcher.
- Entiendo que mi información personal permanecerá confidencial para el investigador.

- I understand that my organization will not be identified either directly or indirectly.
- Entiendo que mi organización no será identificada ni directa o indirectamente.

- I have had the opportunity to have questions answered to my satisfaction.
- He tenido la oportunidad de haber respondido preguntas de acuerdo a mi satisfacción.

Print Name/Nombre:

____

Signature/Firma: ____ Date/Fecha:

____

Contact Address/ Dirección de contacto: ____

Phone Number/ Número telefónico: ____

Email Address/ Dirección de correo electrónico: ____

Appendix 4-C. Interview guide to construction organisations used in the preliminary study

Section 1: General information

- What type of work does the company do? (i.e. Design, Construction, Design and Construction).
- Number of employees (and company profit if possible)
- Qualifications of the personnel (Mention how many employees of each profession the company has).
- Which sector does this organisation work for?
- Which type of projects does the organisations usually develops? (i.e. Residential, Touristic).
- Which type of projects does the organisation usually develop in terms of size? (e.g. Small, Medium, Large).
- Years in the construction industry.

Section 2: BIM awareness and implementation

- Do you know what BIM is? (Explain BIM when needed).
- Is BIM implemented in this organisation?.

For organisations not implementing BIM

- Why is BIM not implemented in this organisation?
- Would this organisation consider the implementation of BIM in the future? Why?

For organisations in transition to implementing BIM and implementing BIM

- What has motivated this organisation to implement BIM?
- How did the organisation prepare for the implementation of BIM?
- Which issues have the organisation experienced in this process?
- What is the scope of the implementation? In which business processes is implemented? (i.e. Architecture design, Engineering, Project Management)

- If the implementation of BIM does not include all the business processes of the organisation, ask the following: Why BIM has not been considered in all the business processes?
- Which resources are used to manage the implementation? (e.g. Protocols, standards, etc.)
- Which benefits has the company obtained from its implementation? (Examples if possible).

For all the organisations

- According to your current knowledge and experience in the industry, could you identify which of these challenges affects the implementation of BIM in the Dominican Republic. Rank them according to their level of importance as follows:

	Very high importance	High importance	Medium importance	Low importance	Very Low importance	Non-importance
High investment						
Cultural resistance						
Lack of BIM skilled personnel						
Learning curve						
Lack of demand						
Lack of BIM guidelines and regulations						
Lack of top management support						

Appendix 4-D. Interview guide to construction organisations used in the main study

Section 1: General information

- What type of work does the company do? (i.e. Design, Construction Design and Construction).
- Number of employees (and company profit if possible)
- Qualifications of the personnel (Mention how many employees of each profession the company has).
- Which sector does this organisation work for?
- Which type of projects does the organisations usually develops? (i.e. Residential, Touristic).
- Which type of projects does the organisation usually develop in terms of size? (e.g. Small, Medium, Large).
- Years in the construction industry.

Section 2: BIM awareness and implementation

- Do you know what BIM is? (Explain BIM when needed).
- Is BIM implemented in this organisation?

For organisations not implementing BIM

- Why is BIM not implemented in this organisation?
- Would the organisation implement BIM in the near future? Why?

For organisations in transition to implementing BIM and implementing BIM

- What has motivated this organisation to implement BIM?
- How did the organisation prepare for the implementation of BIM?
- Which issues have the organisation experienced in this process?
- What is the scope of the implementation? In which business processes is implemented? (i.e. Architecture design, Engineering, Project Management)

- If the implementation of BIM does not include all the business processes of the organisation, ask the following: Why BIM has not been considered in all the business processes?
- Which resources are used to manage the implementation? (e.g. Protocols, standards, etc.)
- Which benefits has the company obtained from its implementation? (Examples if possible).

For all the organisations

- Which challenges do you think hinder the implementation of BIM at a national level?
- Which actions do you think are necessary for the Dominican Republic to propel the implementation of BIM?
- In your view, do you think that the development of a toolkit to guide the implementation of BIM would be beneficial for the Dominican construction industry?

Appendix 4-E. Interview guide for BIM Education

- How did you get interested in the topic of BIM?
- How did prepare yourself academically to acquire knowledge about BIM?
- How did you start delivering BIM education in the Dominican Republic?
- In which ways do you deliver this education? (i.e._Seminars, Conferences, Online courses, Personal training, Group training).
- Which things do you teach to your students?
- Are you planning to expand this delivery of knowledge? If yes, how?
- Which challenges do you think hinder the implementation of BIM at a national level?
- Which things do you think are necessary for the Dominican Republic to propel the implementation of BIM?
- In your view, do you think that the development of a toolkit to guide the implementation of BIM would be beneficial for the Dominican construction industry ?

Appendix 4-F. General information of the participant construction organisations

Org.	No. of employees	Org. classification	Years in the industry *	Sector	City	Type of work	Type of projects	Size of projects	Projects Abroad	Professionals of the construction industry
1	5	Micro-enterprise	30 or more	Private	D.N. (National District)	Design and construction	Residential and commercial projects	Small to medium	No	4 engineers (2 directors, 1 in charge of the purchases and the other one supervisor) and 1 architect
2	5	Micro-enterprise	30 or more	Private	D.N.	Construction and real estate	Residential and commercial projects	Small to medium	No	Civil Engineers (one in charge of purchases) and 1 Architect,
3	200	Medium enterprise	20-29	Private	D.N.	Design, construction. Furnishing of hospitals	Institutional projects (Specialty: Hospitals); Civil works (highways, bridges); and Hydraulic and energy projects (water treatment, hydro-electric power plants)	Large projects	Multinational organisation with headquarters in Madrid	Civil Engineers, Electrical Engineers, Electromechanical Engineers, Architects
4	4	Micro-enterprise	10-19	Private	Santo Domingo Este	Design and construction	Residential and commercial projects	Small to medium	No	Architects only
5	12-15	Micro-enterprise	10-19	Private	D.N.	Design, construction and interior design	Residential (speciality: mountain houses), Commercial and Touristic projects (hotels)	Small to medium	Yes (Haiti)	Architects and Civil Engineers
6	Around 1000	Large organisation	30 or more	Public	D.N.	Supervision	Institutional (Schools, Hospitals) and Civil works (Highways, Dams)	Mainly large	No	Architects, Landscape Architects, Civil Engineers and Electrical Engineers
7	1	Micro-enterprise	5-9	Private	D.N.	Construction more specifically, cost estimation	Varies	Varies	No	Civil Engineer
8	4	Micro-enterprise	20-29	Private	D.N.	Design, construction and properties valuation	Speciality: Civil projects (highways); hydraulic, energy (substations), residential and commercial projects.		No	Civil Engineer (president and properties evaluator) and Architect (Treasurer and vice-president)
9	10	Micro-enterprise	30 or more	Private	D.N.	Construction	Residential, commercial, touristic (hotels), civil works (roads, bridges) Hydraulic (aqueduct, drainage systems) and Institutional projects	Small to Large	No	Civil Engineers only

							(cemetery, sport centre, university buildings)			
10	4	Micro-enterprise	20-29	Private	D.N.	Design and construction	Residential and commercial projects, and urban design,	Small to large	No	Architects only
11	25	Small enterprise	5-9	Private	D.N.	Design and construction	Institutional projects (hospitals)	Large projects	No	Architects and Civil Engineers
12	Around 70	Medium enterprise	10-19	Both, genera lly private	D.N.	Construction management	Residential (private), Commercial, Health and Urban projects (Boulevard). Civil works (roads, asphalt)	Mostly large	Yes, e.g., Panama	Architects, Civil Engineers, Electric Eng., Mechanical Eng., Electromechanical Eng., Technicians, Construction supervisors, Interior Designers and Topographers
13	4 (and 2 associates)	Micro-enterprise	10-19	Both, mainly public	D.N.	Design and construction	Residential, commercial and civil works (pipelines, roads, etc.)	Mainly large	No	Architects and Civil Engineers
14	Between 20-30	Small enterprise	20-29	Private	D.N.	Construction and real estate	Residential projects	Medium to large	No	Civil Engineers only
15	More than 500	Large enterprise	30 or more	Private	D.N.	Construction (Specialty: prefabricated construction);	Civil works (bridges, tunnels), industrial, maritime and commercial projects.	Mainly big projects	Yes (e.g., British Virgin Islands)	Civil Engineers and Architects
16	40-50 employees	Small enterprise	20-29	Private	D.N.	Design, construction supervision, and management	Industrial and commercial projects	Medium to large	Yes (e.g. Colombia, Honduras and El Salvador	Civil Engineers and Architects
17	2	Micro-enterprise	1-4	Private only	D.N.	Construction; electrical and plumbing design; supervision	Residential and commercial projects	Small	No	Civil Engineer
18	8-10	Micro-enterprise	10-19	Private only	D.N.	Design and construction	Residential, commercial and health projects	Varies: small to large	No	Architects and Civil Engineers
19	From 20 to 40	Small enterprise	10-19	Private only	D.N.	Real estate, design and construction	Residential and commercial projects	Mostly large (Projects of 128 and 400 apartments)	No	Architects and Civil Engineers
20	Up to 900	Large enterprise	20-29	Both, more private	D.N.	Construction of metallic structures	Touristic (hotels), commercial and Industrial projects	Varies. More small than large.	Do not know	Structural design, Project installations, Project evaluation, Departments: Commercial, Logistics, Procurement, Management, Production
21	Around 60	Small	20-29	Private	D.N.	Design,	Residential,	Varies. More	No	Architects and Engineers

		enterprise		only		construction and real estate	Commercial, Ecclesiastical and Corporate projects	large than small projects.		
22	Around 70	Medium enterprise	5-9	Public	D.N.	Urban planning	A social project environmental project, urban development and transport	One large social project	No	Architects, Civil Engineers, Electromechanical Engineers, Electrical Engineers; and Engineers with a speciality in Mobility and Transport
23	300-400	Large enterprise	30 or more	Both, more private	D.N.	Construction	Residential projects, hotels (mainly), airports	Mainly large projects	Yes (e.g., Jamaica)	Architects and Civil Engineers
24	2	Micro-enterprise	5-9	Both, more private	Santo Domingo Norte	Design and construction	Private residential; commercial; industrial; and institutional projects (multipurpose room of a school)	Small	No	Employees: Architects Partnership associates: architects, engineers, general technicians and special technicians (30 approximately)
25	Around 220	Large enterprise	30 or more	Both (50-50)	D.N.	Design and construction. Mainly Engineering.	Residential; Touristic (Hotels); Institutional projects (Hospitals, Schools and universities); Civil work (roads, dams, etc.); and airports.	95% are large projects	Yes, (e.g., in Europe)	Architects; Engineering: Civil, Electrical, Mechanical, Soil, Structural, and Plumbing Engineers.
26	32	Small enterprise	30 or more	Mainly private (98%)	D.N.	Architectural design, construction real estate and interior design	Residential projects (apartment towers, houses); Commercial projects (shopping centres, offices buildings, warehouses); airports.	Vary	Do not know	Architects and Civil Engineers
27	2	Micro-enterprise	5-9	Private only	D.N.	Architectural Design; Visualisation; Elaboration of Architectural drawings	Visualisations; Design of commercial projects	Small	No	Architects only
28	13	Micro-enterprise	10-19	Private only	D.N.	Design, construction and real estate (their speciality)	Residential projects	Varies: Small to large projects.	No	Architects and Civil Engineers
29	6	Micro-enterprise	10-19	Private only	D.N.	Architectural design	Residential projects (mainly) and Commercial projects	Varies: Small to medium	No	Architects only

								projects.		
30	78	Medium enterprise	In the country: 5-9; Globally since 1899	Public only (in this country)	D.N.	Construction of Hydraulic projects (in this country)	Sanitation projects (Water supply treatment plants and sewage)	One large project in the country	A multinational organisation with headquarters in France	Architects and Civil Engineers
31	5	Micro-enterprise	5-9	Private	Duarte province	Architectural design and construction (the latter is not widely done)	Residential (apartment buildings, houses); Commercial (Banks, Commercial offices); Landscape; Interior Design; Graphical design	Varies: small and medium projects	No	Architects only
32	8	Micro-enterprise	5-9	Private	D.N.	Project's control	Commercial, Touristic, Institutional projects and Sport centres	Large projects	No	Architect, Civil Engineer, Electrical Eng. And Electromechanical Engineer
33	Around 30	Small enterprise	5-9	Both	D.N.	Design, construction and real estate (their speciality)	Residential projects and Institutional projects (Health projects)	Varies, but mainly large	Yes	Civil Engineers (Project managers, Cost estimation, Resident Engineers) and Architects
34	Around 30	Small enterprise	30 or more	Both, but more private	D.N.	Construction (Contractors)	Commercial, institutional (hospitals), touristic (hotels), and residential projects	Varies. All Sizes	Yes (e.g., Panama)	Architects and Civil Engineers.
35	Around 40	Small Enterprise	5-9	Both	D.N.	Design, construction supervision, direction and process of projects' approval of projects (to the respective Ministries and City Councils)	Residential; Institutional (hospitals, schools), civil (roads, speciality: bridges); and hydraulic projects (dams, aqueducts)	Varies All sizes.	Yes (Haiti and has collaborated with a Canadian company)	Architects and Civil Engineers
36	7	Micro-enterprise	30 or more	Private	D.N.	Design and construction; Interior design	Residential, commercial and touristic projects	Varies. All sizes.	No Have worked with foreign companies	Architects and Civil Engineers

* By the beginning of 2019

Appendix 4-G. Open coding comparison

This Table contains the open coding comparison carried out between the researcher and a PhD colleague in order to ensure the dependability of the data analysis.

Interview questions (Researcher)	Excerpt from interviewees responses (Interviewee 38 form Org. 34)	Open Coding by the researcher (AKS)	Open Coding by PhD colleague (AD)
Which challenges do you think hinder the implementation of BIM at a national level?	I can talk to an Architect and ask: "Why don't you use BIM?". Most of them have expressed their interest already; the real issue is to train people. So, what happens? If Architects, in their professional preparation included BIM knowledge, they would be ready when working in companies and wouldn't need to invest in this. Now it is a problem for them to invest money and time, train their personnel which fluctuates; I mean, I have an architect now, a draughtsman and tomorrow I have another one […] That is the main fear. You invest money on a person; this is very common in Architecture: For instance, you train a guy that become an expert doing renders, and he can do good money as a freelancer, he leaves you because you give him a poor salary working extra hours.	Interest in BIM from Architecture field Education considerations for Architects only Implications of providing training in a company Risk of staff leave after receiving training Low salaries in the industry are one reason	Architects are the most interested in BIM Educate Architects since undergraduate courses Provision of training is affected by the inconsistency of personnel Low salaries are a risk
Are you pointing out low salaries as a problem, then?	"It could be that the preparation comes from the university, that companies don't need to invest that, that be BIM skilled be a requirement to hire personnel and from that point, I think we could it. Because if you know how to model, the rest is more methodological, that is what I think. I think that would contribute more, that it comes from Designers."	BIM education in higher institutions Availability of ready skilled personnel for companies Modelling skills are the most important Focus on training Designers	Offer BIM education in Academic institutions Save money in companies Modelling skills are essential Training to Designers is key

Which challenges do you think hinder the implementation of BIM at a national level?	The main challenge in BIM… How can I say?... Modernisation of the construction methodology. I mean, at a national level, most of the construction companies work on a traditional method from the 70s. We continued building nowadays as the USA used to at the beginning of the 1900s. The access and investment in technology here is not a priority for companies. It is for big ones, but medium and small companies, which are the majority, do not invest in technology. A big company like us, and we are actually not very big, but we do compete with big companies, we can offer BIM, but that requires high investment. So, that the other party do not offer BIM, that the client is not interested… I am not saying exactly; it is just looking for the causes… Clients are not interested; they don't see extra value in BIM. I offer BIM but demand money for that, I mean that raises my professional fees because it costs. Other builders do not implement BIM, but they meet the client's requirements because they are not related to BIM. If the client is not interested, there is no demand. I cannot offer him BIM. If I do not offer BIM, I don't need to train people […] The problem is around these aspects: Offer, demand, training, investment in the personnel, lack of education; I mean, no one knows what BIM is, there is not an institution… Hmmm, if only there were more talks!	Challenges: Traditional way of working Unwillingness to invest in technology Lack of supply chain buy-in Lack of client demand Lack of client demand Investment in BIM Lack of Education Lack of BIM knowledge Initiatives: Diffusion through talks	Adoption of old methods Reluctance to invest in technology Lack of BIM implementation from other parties Lack of interest from clients Lack of demand from clients Investment Lack of BIM Education Spread talks on BIM

Which things do you think are necessary for the Dominican Republic to propel the implementation of BIM?	"Talks, talks, conferences… free." "After creating the demand, the interest will rise in general and yes, you can start offering education." "There must be given more talks, they need to be given not only to constructors but at a national level, I mean, in general, to the final user, and I would say more to this user." "The problem to implement BIM at a national level is this one, lack of knowledge of the final users and the education of the technical personnel that would work under this methodology.	Accessible events Initiatives: Provision of BIM Education Diffusion through talks Challenges: Lack of BIM knowledge Lack of education in the technical workforce	BIM education Spread talks on BIM Lack of knowledge on BIM from final users and technical staff
Improvised: Which other actions would you consider necessary	"The government should always get involved because an awareness campaign costs a lot of money and someone needs to sponsor this. If the government sponsored via MOPC or any other institution oriented to construction the awareness would raise. If MOPC demanded BIM models for projects of certain sizes, for example… I don't know."	Government leadership For financial support To raise awareness Mandate BIM in governmental institutions	Government involvement For financial support To raise BIM awareness Demand use of BIM in public organisations

Appendix 4-H. A transcribed version of one interview (directed to construction organisations.

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26-12-2016

Section 1: General information

[Interview started as a conversation on BIM]

- Interviewee 36: Unfortunately, you need the sheets. The model is not binding, but the blueprints are. I cannot sign, at least here, I cannot sign a contract with a BIM model. I sing it with the blueprints. I find the blueprints from Revit deficient.
- **INTERVIEWER: Why?**
- Interviewee 36: Because there are some customisations that for you to have the work at a professional level, it takes a lot of time. Even, in the USA… From what I have seen, in the USA and in Europe they are used in different ways. In Europe, as a company, I elaborate the BIM model as detailed as possible. Then, I give the model to another company which will do the construction part. This part is the responsibility of the contractor. On the other hand, in the USA, the responsibility is of the Architect. Therefore the product needs to be finished. That is why in the USA, they get to a specific level and from here they use AutoCAD. That is what have given them more results. That is why there are some clashes between the USA and Europe with the implementation of BIM. And, because we are in America, I follow the USA […] It would be difficult for us to work as in Europe when we are actually influenced by the USA.
- […]
- **INTERVIEWER: Could you please tell us your role in the organisation?**
- Interviewee 36: I am the Director of the Drawing Department. The function of this department is the development of the projects, not only drawings but also having control of the construction schedule and the progress of the projects; produce the drawings, and develop certain aspects of the projects.
- **INTERVIEWER: Could you please give a general description of this company?**
    a. ***Design and construction***

- Interviewee 36: This company is mainly dedicated to Engineering: roads, building design, but mainly from Engineering. There is also Architecture but not from the typical Architecture point of view which involves conceptualisation and things like that; it is more like in a constructive way. Normally in companies dedicated only to Architecture, they develop a concept, then the design which is later on sent to the different Technical designers. In this company, it is not this way. We do everything in place, and that is why we integrate all the systems.
- **INTERVIEWER: So, this company has the designers of all the Engineering disciplines?**
- Interviewee 36: Yes. We have Electrical designers, Mechanical. We do Soil science, Structure, Plumbing, Dams […] Everything related to Engineering.
- **INTERVIEWER: So, this company always works for the public sector?**
  - b. ***Both sectors***
- Interviewee 36: Both. I would say is 50-50.
- **INTERVIEWER: You can mention what the company does in general with the exception of what it does in this country. What other things does the company do in general?**
  - a. ***Leisure projects (Hotels)***
  - b. ***Airports***
  - c. ***Roads***
  - d. ***Dams***
  - e. ***Hospitals***
  - f. ***Schools and universities***
- Interviewee 36: Large projects
- **INTERVIEWER: Yes, but which type?**
- Interviewee 36: For example, we developed the XXX in the Dom Rep. We are developing the platform of the XXX XXX hotel.
- **INTERVIEWER: So, the company develops a lot of hotels and civil projects?**

- Interviewee 36: Not many hotels. We were also the company in charge of the transport or of the development of the platform of the Barrick Gold project. I mean, load movement, buildings, the site design. That was a 4-year project. We developed the Punta Cana site.
- **INTERVIEWER: Regarding this project, are you talking about road and things like that?**
- Interviewee 36: The platform. The airport site was designed here.
- **INTERVIEWER: So, this company has a wide variety of projects: From hotels to airports. Has the company developed residential projects?**
- Interviewee 36: We designed the Punta Cana Residential. We did the platform, the division into lots, all these.
- **INTERVIEWER: What about commercial projects?**
- Interviewee 36: No, because these are small projects and we tend to develop large projects.
- **INTERVIEWER: Has the company developed hospitals, schools?...**
- Interviewee 36: Yes, we had a hospital in San Juan. I don't remember the name. It was a refurbishment […] We have supervised schools. We supervised 48 schools for MINERD (Ministry of Education). We did the peer review and then the supervisions. Also, universities. We designed and built UASD in San Juan and Barahona.
- **INTERVIEWER: Regarding civil projects, you said roads, dams…**
- Interviewee 36: Yes.
- **INTERVIEWER: So, the company mostly develops large projects. Can I say that is like a 95% large?**
- Interviewee 36: Yes, something like that. Small projects give problems because when you are used to working with large projects, you think at a high level. You brainstorm, you have a lot of options. On the other hand, in a small project, the client may not be willing to pay all this money and a lot of ideas always emerge. So, in small projects, it does not work.
- **INTERVIEWER: Number of employees:**
- Interviewee 36: I think we are 220.

- **INTERVIEWER: Years in this country**
- Interviewee 36: 30 years exactly.

Section 2: BIM awareness and implementation

- **INTERVIEWER: I have noticed you have some knowledge of BIM. Could you tell me please how you think your understanding of BIM is? Basic, broad?...**
- Interviewee 36: Theoretical, I would say is medium. Practical, low because I took training in 2008, but I didn't like it at all.
- **INTERVIEWER: Which training?**
- Interviewee 36: Revit, but I didn't like it at all. I didn't like what the instructor showed me. I don't like to be restricted by parameters. For example, I love Sketch-up because I have no limits when using the software. But that doesn't happen with Revit or Vectorworks. I tried the latter once.
- **INTERVIEWER: Was this training offered by the company?**
- Interviewee 36: Yes, it was. I learned to Sketch-up and Vectorworks by myself. I didn't like what BIM offered me back then, and I still don't like it, but I understand it is a necessity.
- **INTERVIEWER: Why do you think it is a necessity?**
- Interviewee 36: Because most of the companies in the USA and Europe, in the project development phase, for them to have the same language, they need to implement BIM […] Right now we have a project in Punta Cana with a South African company, and they implement BIM, like in Europe.
- **INTERVIEWER: How are you working with them if they use BIM and you don't?**
- Interviewee 36: There is one thing that, regardless of how cool it looks in BIM, the phase of elaborating construction drawings and drawings that the contractor understands. You know that BIM software is not good to measure. It has restrictions. It is very cool for you too.
- **INTERVIEWER: Hmm, I used to think that, and I have seen people more skilled than me doing the things that for me were not possible.**

- Interviewee 36: That's the problem. That doesn't happen with AutoCAD. You need to be very skilled. You cannot always have people with these skills. I can train a person in AutoCAD to work year and in one year or one year and a half. With BIM, I have no idea how much time I need. The first thing is that the person needs to learn the software at an expert level for me to give him something to do in the software. With AutoCAD, I can give him small task for him to progress, but with BIM I need an expert. That is what I don't like from BIM.
- **INTERVIEWER: How have you acquired the BIM knowledge that you have?**
- Interviewee 36: Reading. Because this is my career and don't let thing to catch me by surprise. And, even though I don't like, that doesn't me I don't look information about it. Because in the end, Revit is the future. Even though America resist to change, depending on how Revit improves, in the end, it will be implemented. I don't know how to tell you because Revit has been in the market for a long time; for like 13 years […] BIM emerged with Revit.
- **INTERVIEWER: You said you read, but which sources do you get information to read from?**
- Interviewee 36: I like a lot the Autodesk page and the forums. I like forums a lot because it's the users […] I see a lot of resistance in Latin America with respect to Revit. They even want to implement it until the development of the projects. After that, they want to continue using AutoCAD.
- **INTERVIEWER: But you know that BIM is not Revit. Revit is a software used in BIM […]**
- Interviewee 36: Yes, because Revit is the one that does all this.
- **INTERVIEWER: Revit is highly used…**
- Interviewee 36: There is other software, but they are not very renowned or are limited to one discipline.
- **INTERVIEWER: Yes, I just wanted to specify that BIM is not Revit; BIM is the process.**
- **INTERVIEWER: Well, BIM is not implemented in this company.**

- Interviewee 36: We are in trying to implement it. A long time ago, the company didn't notice the potential because we were very into public projects or we were working with companies where BIM was not a requirement. From last year, there have been some projects where BIM has been a requirement. Therefore the company has considered it as a necessity now.
- **INTERVIEWER: So, BIM has been demanded in this company?**
- Interviewee 36: Yes.
- **INTERVIEWER: In private projects?**
- Interviewee 36: Yes.
- **INTERVIEWER: Dominican companies?**
- Interviewee 36: No. In the national market, I think only a few Architectural firms implement BIM. Because, as far as I know, with companies I subcontract, for the technical disciplines they hire freelance professionals, but there is not a company that specifically offers the MEP or Revit Structure service. There is not any. Only a few Architectural companies offer this, but the remainder companies subcontract people skilled in the software.
- **INTERVIEWER: How is the organisation preparing for the implementation of BIM?**
- Interviewee 36: Well, we are taking a Revit Training. Regarding CAD, here there are two Departments: The Drawing Department, which is in charge of the development of the project and the Transport Department. This latter use Civil 3D, and that's actually BIM. And in the Drawing Department, we are currently using AutoCAD, and we took the first training of Revit, and we are about to take the second training to start implementing BIM in the company.
- **INTERVIEWER: Who of the personnel are taking this training?**
- Interviewee 36: All the personnel of the Drawing Department.
- **INTERVIEWER: Of all the disciplines?**
- Interviewee 36: Yes, Engineering and Architecture. We took the Architecture module, and now we are going to take the Advanced module of Architecture and MEP.

- **INTERVIEWER: So, the company is not using Revit yet until the personnel are trained?**
- Interviewee 36: Yes, we still use AutoCAD.
- **INTERVIEWER: So, you have not been able to experiment with BIM yet.**
- Interviewee 36: No.
- […]
- Interviewee 36: I think that the person in charge of the implementation of BIM in the company is very optimistic. She says that with another training the company can start offering BIM and I have a dissident opinion. Because it is not the same. When a person graduates and is in charge of a Department right after, he will make a lot of mistakes. I consider that the correct thing is to start with a low or medium area until you get the experience to do more things. This thing is finishing training and start the implementation right after is not right […] I don't think the implementation will be that fast.
- **INTERVIEWER: This person you are talking about is not from the company, right?**
- Interviewee 36: No, is not.
- […]
- Interviewee 36: Not always the person in charge of the implementation is right […] I see the BIM champion of this company very optimistic when I know it's not like that. I know two companies that have years in the process, and they haven't been able to. We won't do it in one month.
- **INTERVIEWER: When you mention the BIM champion, you are referring to the person you previously talked about, right?**
- Interviewee 36: Yes. She is practically the adviser. She is the one the company is trusting to give us the guidelines of where we need to go and what we need to do. And, as I said I always see she is very optimistic. I want to see here more realistic […] The fact that you do it, doesn't mean that others… If you have 13 years using it, that doesn't mean that, in one month, after taking training, I will be at your level. That is being very optimistic.
- […]
- And the target of this company is level 2, and that is aiming too high.

- **INTERVIEWER: Level 2, following which standards?**
- Interviewee 36: Americans.
- […]
- **INTERVIEWER: Who established the level 2 for the implementation of BIM in the company? The BIM champion?**
- Interviewee 36: No, the company.
- […]
- Interviewee 36: Contrary to the BIM champion estimations, I think that at the end of next year we will need to have at least one person of the company at an expert level. No, actually, I want to have at least 3 experts by the end of next year.
- **INTERVIEWER: So, the company will be implementing BIM by the end of next year.**
- Interviewee 36: No, before. I want to see if, at the end of April, we can at least offer the service but, obviously, my goal is to prepare 3 experts by the end of the year.
- […]
- **INTERVIEWER: Which challenges do you think hinder the implementation of BIM at a national level?**
- Interviewee 36: BIM is for countries that follow regulations. In a country where there is not a drawing standard; where we still have still two projects: one to be approved and another one to be built; where there are so many construction defects in buildings; where you talk to Architects, and most of them don't know how to integrate all the disciplines; where everything is solved on-site. While this is the criteria, BIM is far away. At least for BIM to be a requirement, that is very far away.
- **INTERVIEWER: When do you think that will be possible?**
- Interviewee 36: I think that from when I learned AutoCAD to now, the country has not advanced much. I receive projects that look the same way they were drawn when I started to use AutoCAD because there are no school dedicated to this […] When you finish your career where you don't know what a working platform is. You don't even know how to create one. You don't know how

communication and collaboration in a project is. You have no idea. Unless these aspects become requirements, BIM will be implemented in like 20 years. While BIM doesn't be demanded and the most important companies in the country don't want to improve and just care about making money, BIM is far away. Most of the Dominican professionals are taught to make money and not to improve. That's the issue. BIM means improvement and because the country doesn't want to improve and most of the professionals what really care is about making money, the implementation of BIM is quite difficult. BIM is still a dream in developed countries.

- […]
- Interviewee 36: But to me, the main one, the barrier that we need to face, is that professionals must have the need to improve. And most of the professionals don't want to improve. There is also a lack of collaboration […] While the collaboration culture is not present in the Dominican construction industry, implementing BIM will be difficult… BIM is a collaboration platform because is not limited to the design phase only. It involves cost estimation, supervision, all these things. We need to switch the mentality. If not, BIM will be underused.
- […]
- **INTERVIEWER: Which actions do you think are necessary for the Dominican Republic to propel the implementation of BIM?**
- Interviewee 36: You mean at a national level?
- **INTERVIEWER: Yes.**
- Interviewee 36: I would say that to start implementing BIM, we would need to start from universities because AutoCAD got popular when universities added it as a requirement. Until universities didn't get involved in this, there was no way to put AutoCAD as a requirement. If you start with the universities. Because that's the good things in universities. You will have people for 4-5 years there. You, as an interested person in implementing BIM, need to insert it into the curriculum. Once a person finishes his careers, for him it will be easy, and he will want to improve only. When he starts working, he will have other ideas and another mentality […] If it is post-university it won't happen because it won't be a requirement, it won't be in your head.
- […]
- Interviewee 36: It needs to start from universities. Once the new professions think about BIM, eventually will appear a person in the government with the

idea, and people will join and will become a requirement. But for this to happen, you need education from universities.

- **INTERVIEWER: In your view, do you think that the development of a toolkit to guide the implementation of BIM would be beneficial for the Dominican construction industry?**
- Interviewee 36: That will be automatic. If you prepare them academically in the university when they finish, they will look for the way to implement BIM and make it possible, but it needs to start from the university [He talks about how he trains people in the company] If you are taught from the university, and you apply it as a culture, with all its benefits, when they go to a company that uses AutoCAD, they will change the mentality of the company, and little by little will guide the implementation of BIM in the company.
- **INTERVIEWER: But if there were regulations or tools that guide companies…**
- Interviewee 36: No. Regulations are not met in this country.
- **INTERVIEWER: So, for you, every company should implement it on its way.**
- Interviewee 36: The problem is that I don't think the government will get involved in this.
- [….]
- **INTERVIEWER: The toolkit I am talking about would be like a guide, don't need to be something governmental.**
- Interviewee 36: I see it quite ambitious to come from the government.
- […]
- Interviewee 36: Well, as I said, if you teach people at the universities, at the end they will implement the platform this way. And, little by little, they will change the mentality of the country. In a matter of 5, 6, 7, 8 years, I think that the country will opt for this methodology because most of the new professionals will come with new ideas. But if you don't start with universities and put it as a requirement from the government, instead, no one will follow it. Because think about it, the government doesn't even regulate the working platforms. The government restricts only to the M-21, which is the regulation about the project's submission requirements. These are from the ISO regulation, which dates from the 50s […] This regulation asks basic things for the project: floor plans with dimensions, architectural plans, elevations, sections and some details […] On the

other hand, international regulations, from the USA and the UK, the information you need to present before starting the project is enormous. Because the idea is that the project is very similar to what it was designed and that the cost estimation is very similar to what was calculated [...] If you teach this from the university, they will continue implementing it. The problem is that universities here still follow the ISO methodology.

- **INTERVIEWER: So, the challenge would be the people that are already professionals.**
- [He gives an example of how the education system changed in Japan]
- Interviewee 36: From now on, unfortunately, who is in this country needs to hustle. Sometimes you need to be drastic. If you do it gradually, it takes you 10 times more than a drastic method […] Also, people that finish university needs to adapt because universities don't have any commitment with graduates, but with current students. The curricula need to be modified for that. For the professionals, you give them a deadline, you create training and they will adapt with time […] The change from drawing by hand to AutoCAD was not very drastic because, in essence, is like drawing by hand but with a computer […] I experienced this change. When I was studying, everything was by hand but then, the boom of AutoCAD started in 2000, and I did not want it. To me, that was a high investment in computers [He makes an analysis of how expensive was a computer back, internet and other things back then] I started using AutoCAD because the company where I was working had the software. And after that, I started realising that companies would get fewer clients or that companies were not demanded people by hand drawings skills, so I started to change. The same thing that is happening with BIM now. The difference is that the transition to BIM is slower […]
- […]
- Interviewee 36: Unfortunately […] For you to notice the cultural backwardness in this country, universities don't even know which methodology they are implementing in Architecture, for example […] I can assure that any professor cannot tell you the method he is implementing or which platform they are using. If they don't know, how can they improve?
- [...]
- **INTERVIEWER: … For the BIM implementation plan in this company, you only mentioned the software Revit.**

- Interviewee 36: Oh, it is because Autodesk changed its methods. Before you would buy the software; now you buy the whole package. Navisworks was purchased. It is there, and after we finish the MEP training, we need to start using Navisworks.

Appendix 8-A. Initial framework for BIM Education

BIM Education Framework for Clients and Professionals of the construction industry

<table>
<tr><th colspan="5">Academia</th></tr>
<tr><th rowspan="2">Strategy stage</th><th colspan="3">Implementation stage</th><th rowspan="2">Revision stage</th></tr>
<tr><th colspan="2">Actions</th><th>Participants involved</th></tr>
<tr><td rowspan="6">Creation of groups with members from Academia and the industry to lead the strategy;
Identification of the BIM abilities needed per discipline from the educators;
Identification of the BIM skills per discipline required from the students;
Categorisation of these abilities by themes, according to the knowledge disciplines of the construction industry.</td><td colspan="2">Provision of education and training required for the educators.</td><td>Academics
BIM education providers
Industry</td><td rowspan="6">Assessment of the programs created by getting feedback from:
BIM learners: to express their opinion about program and learning outcomes;
Academics: by analysing the progress and performance of the students
Industry: by the evaluation of the BIM learners skills when practical implementation activities are programmed.</td></tr>
<tr><td colspan="2">Elaboration of the learning modules:
To be embedded in current programs; and
For the creation of new programs.</td><td>Academics
Industry
BIM education providers
BIM learners
Researchers
Government (as support)</td></tr>
<tr><td colspan="2">Creation of BIM learning materials for new modules inserted and programs modified.</td><td>Academics
Industry
BIM providers
BIM learners
Researchers</td></tr>
<tr><td colspan="2">Practical implementation of the knowledge acquired:
Knowledge transfer partnerships;
Internships;
Co-ops.</td><td>Academics: for planning;
Industry: to provide opportunities to the BIM learners;
Government: to promote this practice in BIM education.</td></tr>
<tr><td colspan="2">Diffusion of other BIM type of education and activities for knowledge boosting and acquisition of transferable skills through workshops, conferences, seminars, etc.</td><td>Academics
BIM education providers
Industry
Government</td></tr>
<tr><td colspan="2">Establishment of minimum knowledge requirements to undertake higher education degrees such as masters and research. That is to avoid teaching new things to students that have some gaps in knowledge.</td><td>Academics
Industry: to identify problems in practice and propose research in the field.</td></tr>
<tr><th colspan="5">Industry</th></tr>
<tr><th rowspan="2">Strategy stage</th><th colspan="3">Implementation stage</th><th rowspan="2">Revision stage</th></tr>
<tr><th colspan="2">Actions</th><th>Participants involved</th></tr>
<tr><td>Designation of a BIM Champion to lead the strategy;
Identification of the BIM scope of the company;
Identification of the BIM abilities required per role in</td><td>BIM Education for the staff</td><td>Higher education: Large funding needed. Suitable for large companies with considerable budget dedicated to training</td><td>Provided by:
Academia</td><td>Evaluation of the performance of the staff and the client;
Comparisons of project outcomes and performances before and after the strategy.</td></tr>
</table>

the organisation; Identification of the training to be taken by the staff depending on their role in the team and requirements of the type of projects: Managerial levels; Remainder staff; The client, when needed.		Acquisition/upskill of software abilities:	Provided by: Software developers; Expert(s) hired by the organisation; or Skilled staff from the company designated by the BIM champion.	
		Acquisition of different transferable skills: CPD programs Attend workshops, conferences, seminars, etc.	Provided by: Organisation; and BIM education providers	
	BIM education to the client	To receive consultancy in the following areas: Introduction to BIM; Establishment of BIM goals for the project; Documentation management.	BIM consultant from: The organisation; or An independent BIM consultant.	

Appendix 8-B. Cover letter for the framework validation process.

VALIDATION OF A FRAMEWORK FOR IMPLEMENTING BIM IN THE DOMINICAN REPUBLIC

Dear participant,

My name is ANA KARINA SILVERIO RODRIGUEZ. I am currently in the last stages of my PhD research "Framework for implementing BIM in the Dominican Republic", which you kindly took part of in the data collection process. The outcome of the research is a framework to implement BIM which requires to be validated by the participant's study since they have been key figures in its development. Therefore, I would like to formally invite you to be part of the validation process of the proposed framework.

If you agree to participate, you will be required to:

- Read the validation guide in the PDF file to understand the rationale of the framework (of 10 minutes approximately). Then, you will need to fill in a Google Forms document with open and closed questions regarding the presented framework. The questions will be specific to aspects of the framework and participants are welcomed to give any recommendations, if necessary, for further improvement.

Your answers will be stored and used exclusively for the validation of the framework. If you wish, the form can be reviewed, edited or erased. Your anonymity will be maintained, and the information you provide will be treated as confidential.

Once the framework is validated a summary of the results will be available when the work is officially submitted. If you wish to obtain a copy of those results, please provide your contact details. Please note, that all the information collected in this investigation will be safely stored and destroyed after the thesis is delivered. My supervisors Dr. Subashini Suresh, Dr. David Heesom and Dr. Renukappa Suresh and I will be the only people who will have access to this information.

Thank you for your time in considering this invitation and, if you agree to participate in this research, I would like to extend my gratitude for your contribution as it is greatly appreciated.

University of Wolverhampton

Wulfruna Street, City Campus

WV1 1LY

[redacted]

[redacted]

Appendix 8-C. Framework validation questionnaire online

Framework validation

Descripción del formulario

Dirección de correo electrónico *

Dirección de correo electrónico válida

Este formulario recopila las direcciones de correo electrónico. Cambiar configuración

Profession *

Texto de respuesta corta

Years of experience in the industry *

- 5 years or less
- 6-10 years
- 11-20 years
- 21- years or more

How long have you been knowledgeable on BIM? *

- 1- 3 years
- 4 - 6 years
- 7 - 9 years
- 10 years or more

How long have you been implementing BIM? *

- 1-3 years
- 4-6 years
- 7-9 years
- 10 years or more
- Does not apply

How long have you involved in teaching BIM and BIM-related topics? *

- 1-3 years
- 4-6 years
- 7-9 years
- 10 years or more
- Does not apply

BIM qualifications *

- Yes
- No

Indicate BIM qualification

Texto de respuesta corta

What is your opinion about the content of the framework? *

Texto de respuesta larga

What is your opinion about the framework's structure? *

Texto de respuesta larga

Do you think that the framework is easy to understand? *

- Yes
- No

Do you think that all the information contained is relevant? *

- Yes
- No

Is this framework suitable for the Dominican Republic? Why? *

Texto de respuesta larga

Would you please provide any recommendations, if needed, to improve the proposed framework?

Texto de respuesta larga